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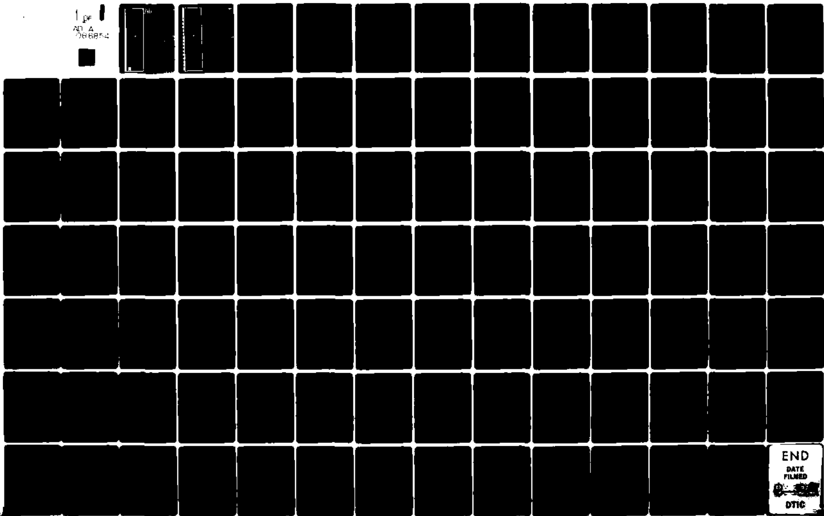

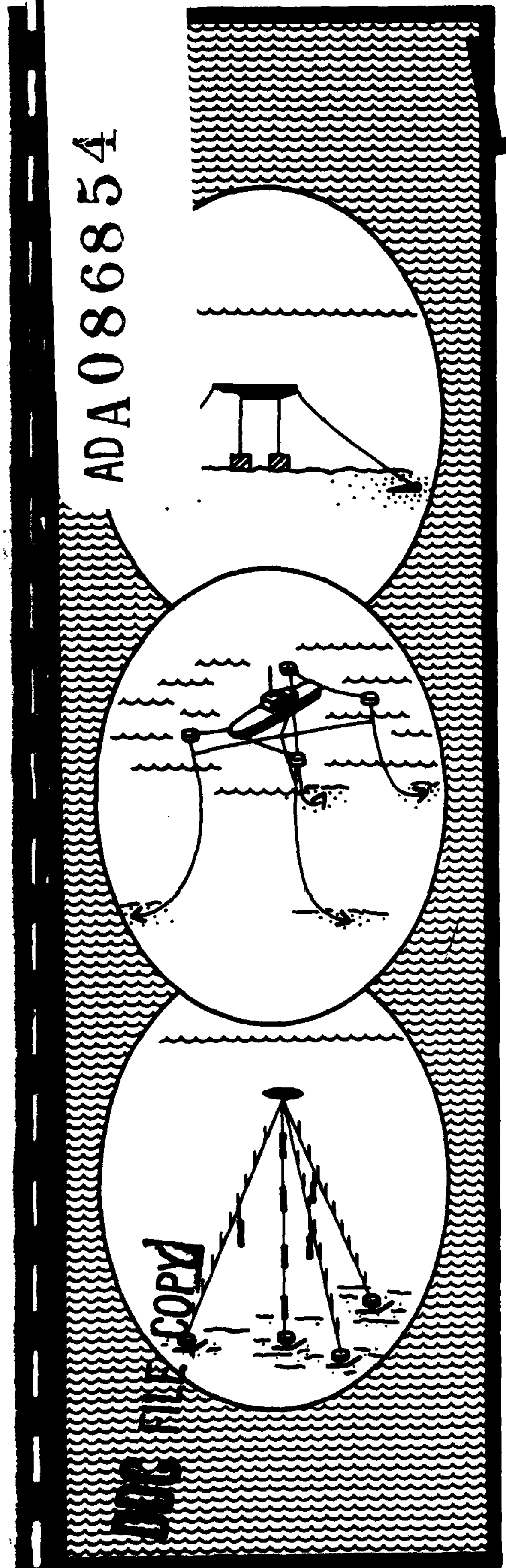

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MOORING DYNAMICS: COMPUTER MODELS AND EXPERIMENTS AT A SIXTY FOOT SCALE

By

DAVID B. DILLON

Prepared for

Civil Engineering Laboratory
Naval Construction Battalion Center
Port Hueneme, California 93043

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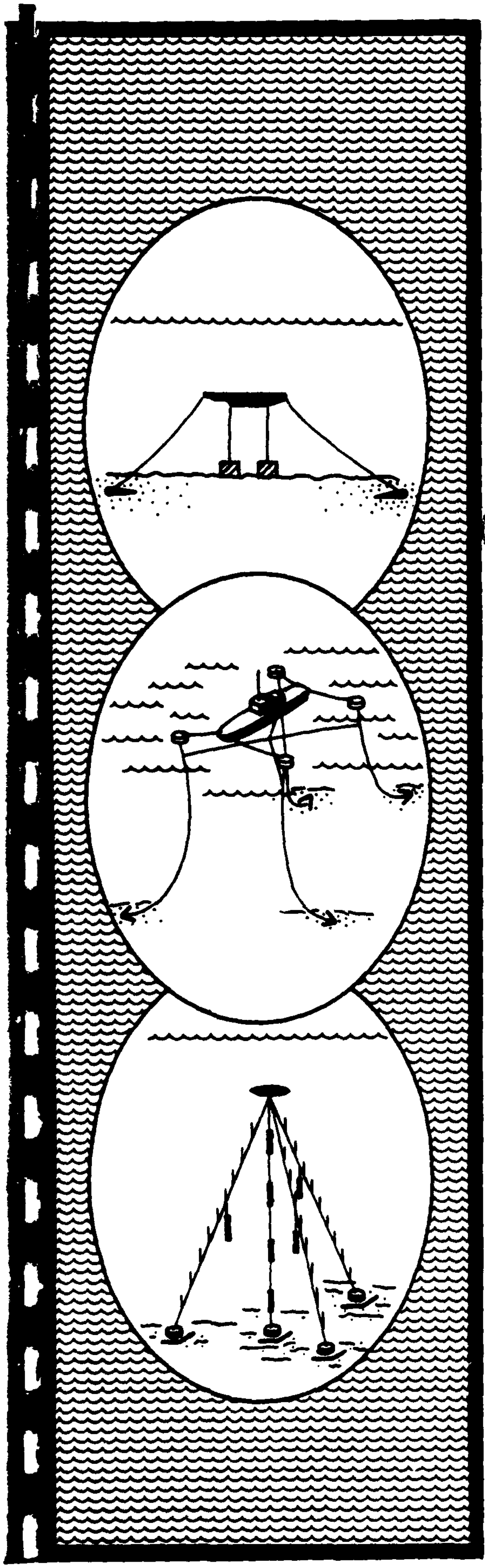

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By

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The U.S. Navy Civil Engineering Laboratory is conducting a series of dynamic cable experiments in order to evaluate computer models of cable systems used in the ocean. The results of an experiment using 60 foot cables are compared to two computer simulations in this report. Other experiments at scales of six feet and 2,500 feet have been performed.

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Three cases from the experiment conducted in the hydroballistics tank of the Naval Surface Weapons Center in 1976 are compared to the SNAPLOAD and SEADYN computer models. Two of the runs simulate the anchor-last deployment of a mooring; the third shows the relaxation of a mooring displaced laterally, then released.

The quality of the experimental data is evaluated by comparing each case to the static, elastic catenary equations at the start and finish of each run. The measured positions of points along the static catenaries are found typically to agree with the catenary calculations within 1 to 2 percent of the cable length. Tension measured at the fixed end typically agrees with the calculated value within about 12 percent.

The SEADYN and SNAPLOAD computer models are found to reproduce all the significant motion and forces observed in the experiment. The "handbook" drag coefficients programmed in these models allow the cable motion sometimes to lead the data, sometimes to lag behind. More specific coefficients must be used when the rate of the dynamic motion is critical.

Neither model included elastic hysteresis. The SEADYN program gave somewhat erratic tension values in the mooring line because tension waves were not damped by hysteresis. The SNAPLOAD model eliminated the tension variation through artificial damping.

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ABSTRACT

The U.S. Navy Civil Engineering Laboratory is conducting a series of dynamic cable experiments in order to evaluate computer models of cable systems used in the ocean. The results of an experiment using 60 foot cables are compared to two computer simulations in this report. Other experiments at scales of six feet and 2,500 feet have been performed.

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SECTION I
INTRODUCTION

The Civil Engineering Laboratory (CEL) is developing two computer models for simulating and analyzing the dynamics of cables suspended in the ocean. The SNAPLOAD program is a model of the response of serially-connected segments suspended in a vertical plane. The SEADYN model treats cable networks in three dimensions. A series of experiments using instrumented cables has provided a standard of comparison for evaluating these models as engineering design tools.

The first experiment[1] in the series used a soft silicone rubber cable about six feet long. The experiment described in this report used a length of about 60 feet[2]. A third experiment is the Mooring Dynamics Experiment conducted in about 2500 feet water off Kauai, Hawaii in 1976[3], using materials typical of oceanographic moorings.[4] Finally, an experiment using an instrumented barge mooring is planned.[5]

Of the 15 experimental cases in the 60-foot series, three have been selected for comparison with SEADYN[6] and SNAPLOAD[7]. Two of the runs simulate the anchor-last technique for deployment of a mooring. The ends of the mooring line are supported at the water surface, with the mooring line hanging in a catenary between the supports. The anchor at one end is released and drops toward the bottom (Figure 1-1). The other run simulates the relaxation response of a mooring to a step-function perturbation. The mooring buoy is moved from its equilibrium position over the anchor and released (Figure 1-2). Response to a step function is a standard test applied to dynamic systems.

A triaxial force gauge measured the tension vector at the fixed end of the cable during each run. The gauge signal was digitally recorded on magnetic tape once each second.

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[1] Superscripts identify references by number.

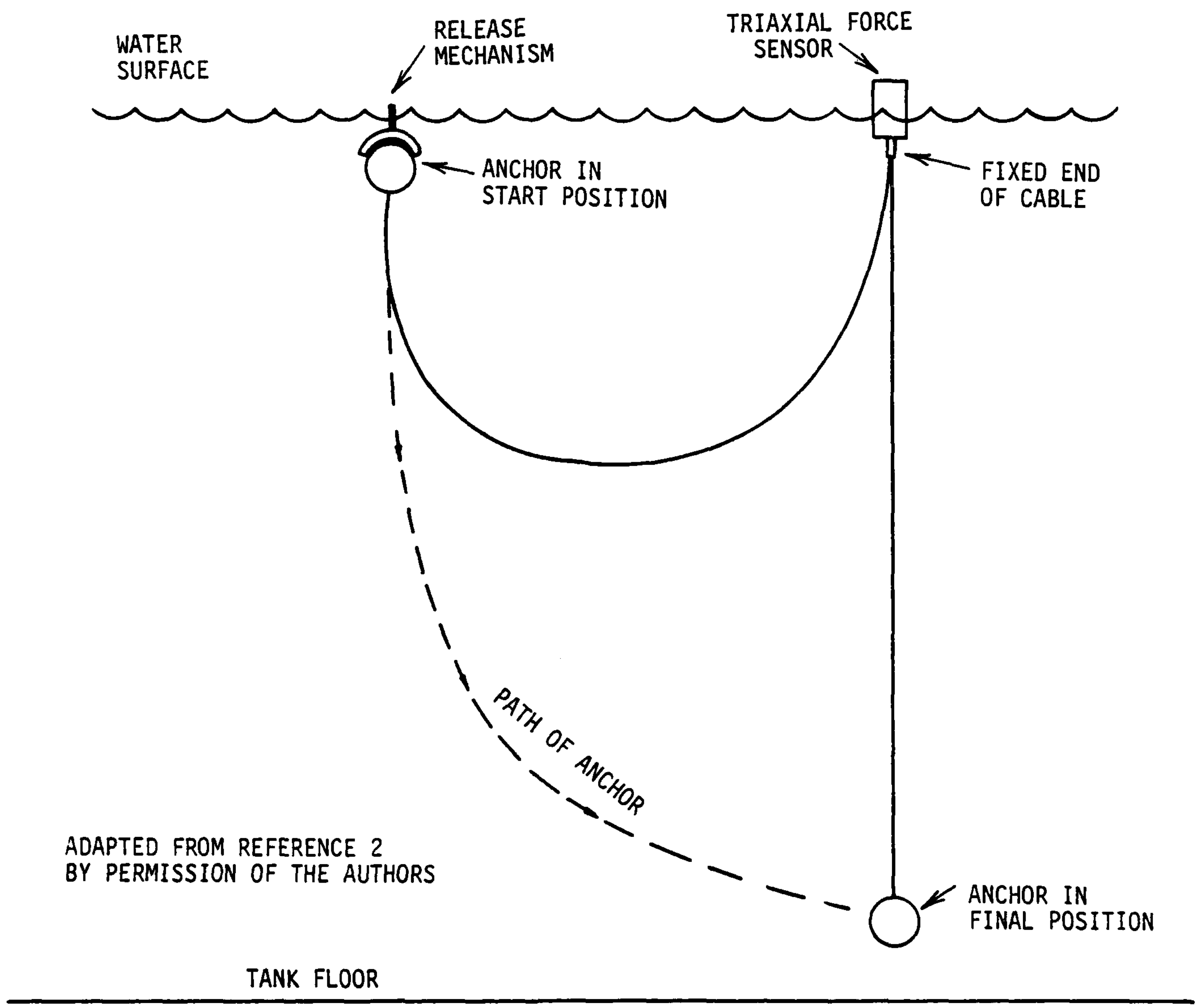


Figure 1-1. Anchor Last Deployment Simulation

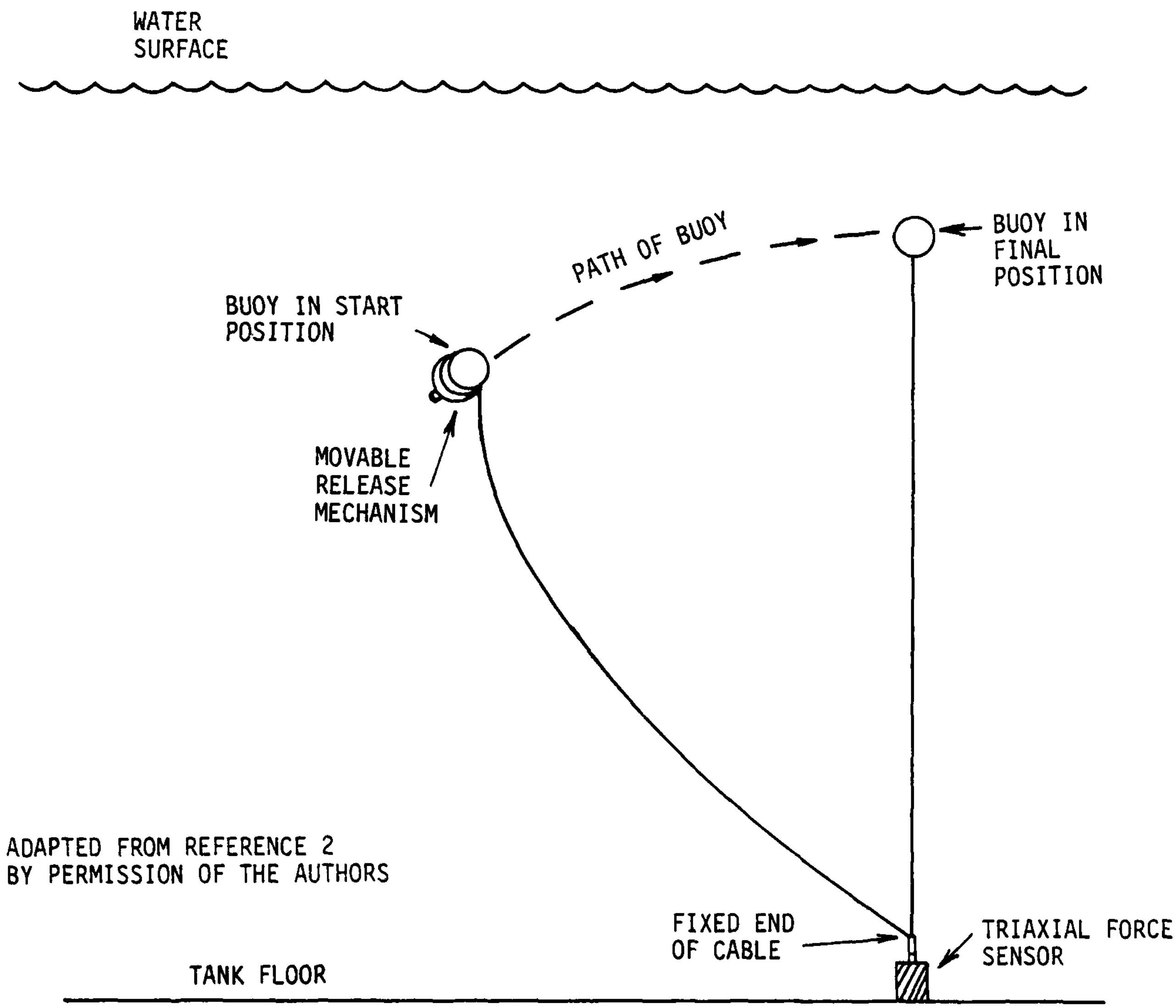


Figure 1-2. Buoy Relaxation

Small lamps attached to the mooring cable at six foot intervals were flashed each second during a run. The flashes, coincident with the force gauge samples, were photographed through a window in the darkened tank. The photographs, whose appearance is similar to the trajectory plots shown in Section VI, were analyzed against a calibrated grid. The result is a table giving the position of each lamp at the moment of each flash.

Run 6 was an anchor-last experiment using 55 feet of line with supports 21 feet apart. Run 11 was the relaxation experiment using 51 feet of line. The buoy was deflected about 31 feet horizontally and 18 feet down. The silicone rubber cord was allowed to come to equilibrium before the buoy was released. Run 15 was the other anchor-last deployment, using an anchor about 2.5 times as heavy as the anchor in Run 6. Initial conditions for Run 15 were the same as for Run 6. Appendix A gives tables of the shapes and tensions measured for these runs.

The relaxation experiment is not as dramatic as the anchor-last cases are. This is because the initial catenary of the line between the fixed anchor and the deflected buoy has the same sense of curvature as the catenary during the relaxation. The mooring is clearly overdamped and recovers its vertical orientation asymptotically.

The very slack initial catenaries of Runs 6 and 15 have a sharp curvature opposing the hydrodynamic forces generated during the anchor drop. Furthermore, the terminal velocity of the anchor is substantially greater than the terminal velocity of the line. The transverse drag of the cable is also much greater than the cable's tangential drag. These factors combine so that shortly after the anchor is released, the cable becomes N-shaped. This shape stretches out as the anchor falls nearly straight down (the cable is too slack to deflect the anchor) until either the cable snaps taut (in these experiments that simulate a subsurface buoy mooring) or the anchor impacts the bottom (in the case of a surface buoy mooring). Then, the mooring drifts into a vertical mode like an inverted relaxation.

SECTION II
EVALUATION OF EXPERIMENTAL RUNS

2.1 GENERAL.

Fifteen cases were run using the apparatus described in Reference 2. Each run began and ended with the mooring line in a static condition. Since the static shape and tension distribution are expressed in relatively simple formulae, the quality of the dynamic data gathered during a run can be inferred by comparing the initial and terminal measurements of cable shape and tension to the static calculations. Appendix B gives details of these comparisons, which are discussed in the paragraphs that follow.

2.2 RUN 6: ANCHOR-LAST.

The positions of seven points along the cable were recorded prior to releasing the anchor and compared to the static elastic catenary formulae. The mean radius from a measured point to the corresponding point along the catenary was 0.5 feet with a standard deviation of 0.4 feet. The mean radial error is about one percent of the length of the cable.

The cable force on the load cell was calculated to be 0.068 pound at 81.8 degrees below horizontal. The output of the load cell was 0.058 pound at an angle of 76.7 degrees. The standard deviation of the load cell calibration is 0.007 pound. The remainder of the discrepancy must be accounted in the standard deviations of the measured cable weight and elasticity used in the catenary formulae.

By 90 seconds after the anchor was released, the mooring had virtually stabilized: drag forces were negligible. The elastic catenary equations were solved using the measured weight and horizontal displacement of the anchor as boundary conditions for this case. The mean distance between the measured and calculated node positions at $t = 90$ seconds was 0.7 feet with a standard deviation of 0.5 feet. This corroborates the one percent error noted for $t = 0$.

The immersed weight of the cable and anchor in Run 6 is about 0.240 pound. The load cell output was 0.221 pound at the end of the run, 100 seconds after the anchor was dropped. The load cell recorded the cable angle as about five degrees from vertical. This reflects an exponential approach to vertical equilibrium.

2.3 RUN 11: BUOY RELAXATION.

At the start of Run 11, the mean radius between the calculated and measured locations of seven points along the cable was 0.8 feet, with a standard deviation of 0.4 feet. The initial tension was calculated to be 0.027 pound at 12.9 degrees below horizontal. The load cell output was only 0.0013 pound at 37.7 degrees below horizontal. The tension after 100 seconds was measured as 0.271 pound at 9.2 degrees from vertical. The tension due to weight and buoyancy was 0.308 pound.

The measured state of this mooring at t = 90 seconds was compared with the state calculated for a static, elastic catenary, using the buoyancy and displacement of the buoy as boundary conditions. The horizontal difference averaged 0.7 feet, but the mean vertical difference was 3.2 feet, so that the mean distance for the seven nodes was 3.3 feet, with a standard deviation of 0.2 feet. The data for other times are consistent with the results at 90 seconds. All nodes show a smooth trajectory from start to finish.

2.4 RUN 15: LARGE ANCHOR-LAST.

The seven points compared for this run averaged 0.8 feet difference between measured and calculated location prior to anchor release. The standard deviation was 0.3 feet.

The comparison at the end of Run 15 is as good or better. The mean distance is 0.6 feet with a standard deviation for eight nodes of 0.4 feet.

The calculated initial tension was 0.068 pound at 82.0 degrees from horizontal. The load cell read 0.060 pound at 80.1 degrees. After 100 seconds, the load cell read 0.374 pound at 8.9 degrees from vertical. The combined cable and anchor weight for this case is 0.384 pound.

2.5 RUN SUMMARY.

In comparing the results of the computer models SEADYN and SNAPLOAD to these three experiments, discrepancies of one foot between corresponding cable points may be attributed to experimental uncertainty. The positions tabulated for Run 11 may have larger errors. The calibration grid used to digitize the photograph for this run may have been misaligned.

Tensions within about 0.025 pound may also be taken as equivalent.

SECTION III
MODEL DESCRIPTIONS

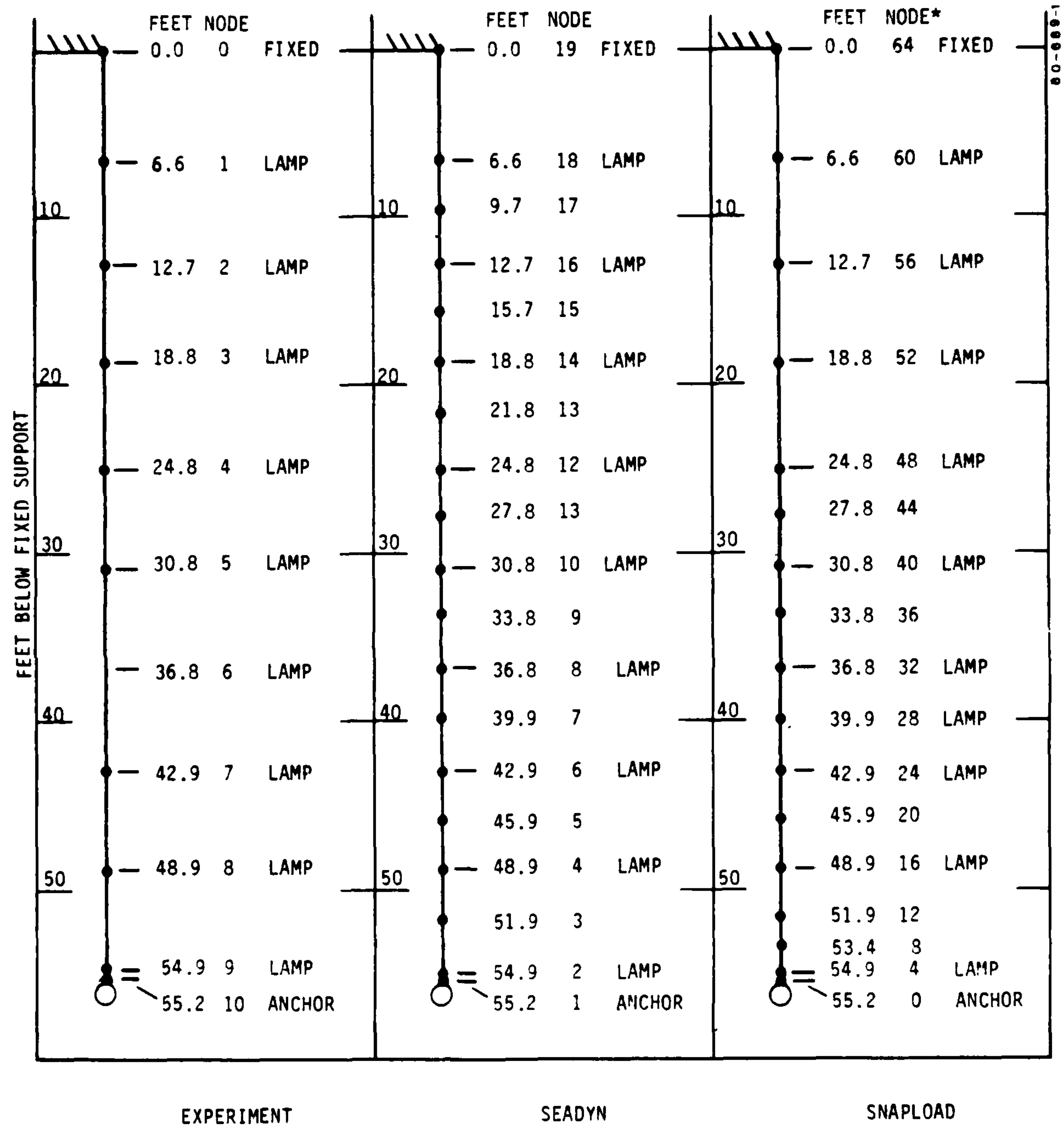
Both SEADYN and SNAPLOAD model a mooring cable as a series of straight elastic elements joined at nodes. All bending is concentrated at the nodes. which may be thought of as frictionless universal joints. The models differ in the mathematical formulation and the resulting computer code expressing the interactions of these nodes and elements with the fluid environment. It is not the purpose of this study to delve into the mathematical theory for these codes; that is presented in the respective user's manuals.

However, the modeling process does not stop with selection of one computer program or the other. Both programs, but especially SEADYN, contain a variety of options; some of these options are predetermined by the problem statement. If no ships are attached to a cable system, then obviously the ship-motion options are rejected. Likewise, the cable material determines which stress-strain relation is correct. But other choices remain at the discretion of the user. The most obvious of these are the number and location of nodes along the mooring line. If the user selects too few nodes, the calculations may not correspond to reality, if indeed the computer is able to converge upon a solution at all. If on the other hand, too many nodes are used, the efficiency of the program can be seriously reduced, with consequent increases in cost.

When irregularly shaped objects are attached to the mooring, the user must estimate the properties of an equivalent simple shape. The important point is that the model of a mooring is not completed by the selection of a computer program. The user assumes the role of modeler as he prepares input data for the program. There is currently no "cookbook" for this process, nor will the completion of this experimental test and validation series provide one. The validity of results of simulations using these programs will depend significantly on the judgment, experience, and care shown by the user.

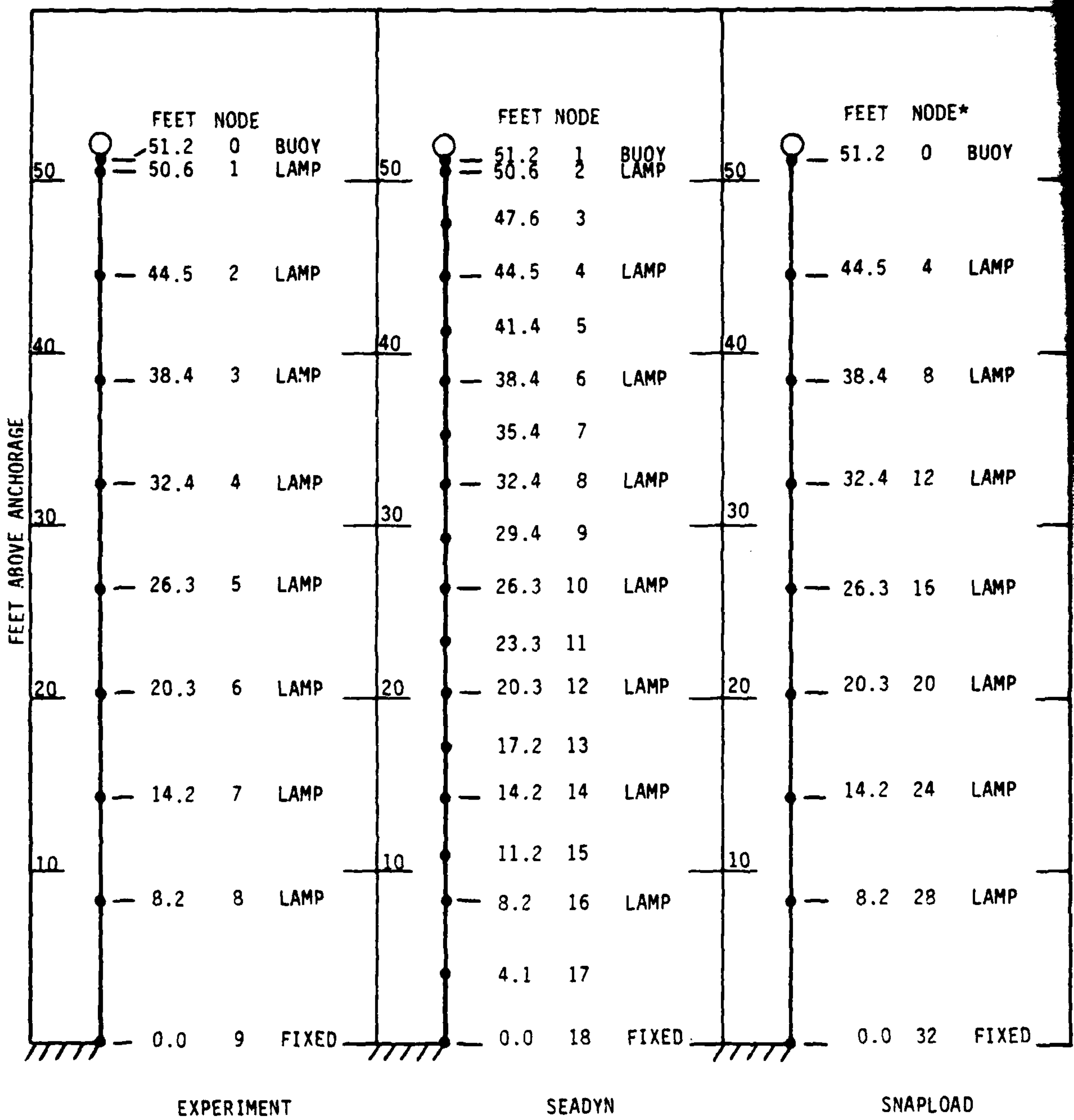
In order to make the comparison of these two models as independent of user influence as possible, the experiments were designed to be physically simple. The mooring line was a single strand with uniform properties, and the anchors and buoys were spherical. Furthermore, the same node distribution was used for both programs.

Figures 3-1, 3-2 and 3-3 show the node assignments for the three runs, respectively. These schematic representations show the distribution of lamps along the relaxed rubber line and the corresponding distribution of nodes for the SEADYN and SNAPLOAD models. In each case, the models have nodes corresponding with lamp locations. During the experiment, the cable shape was recorded by flashing the lamps at regular intervals in a darkened chamber. The flashes were photographed.



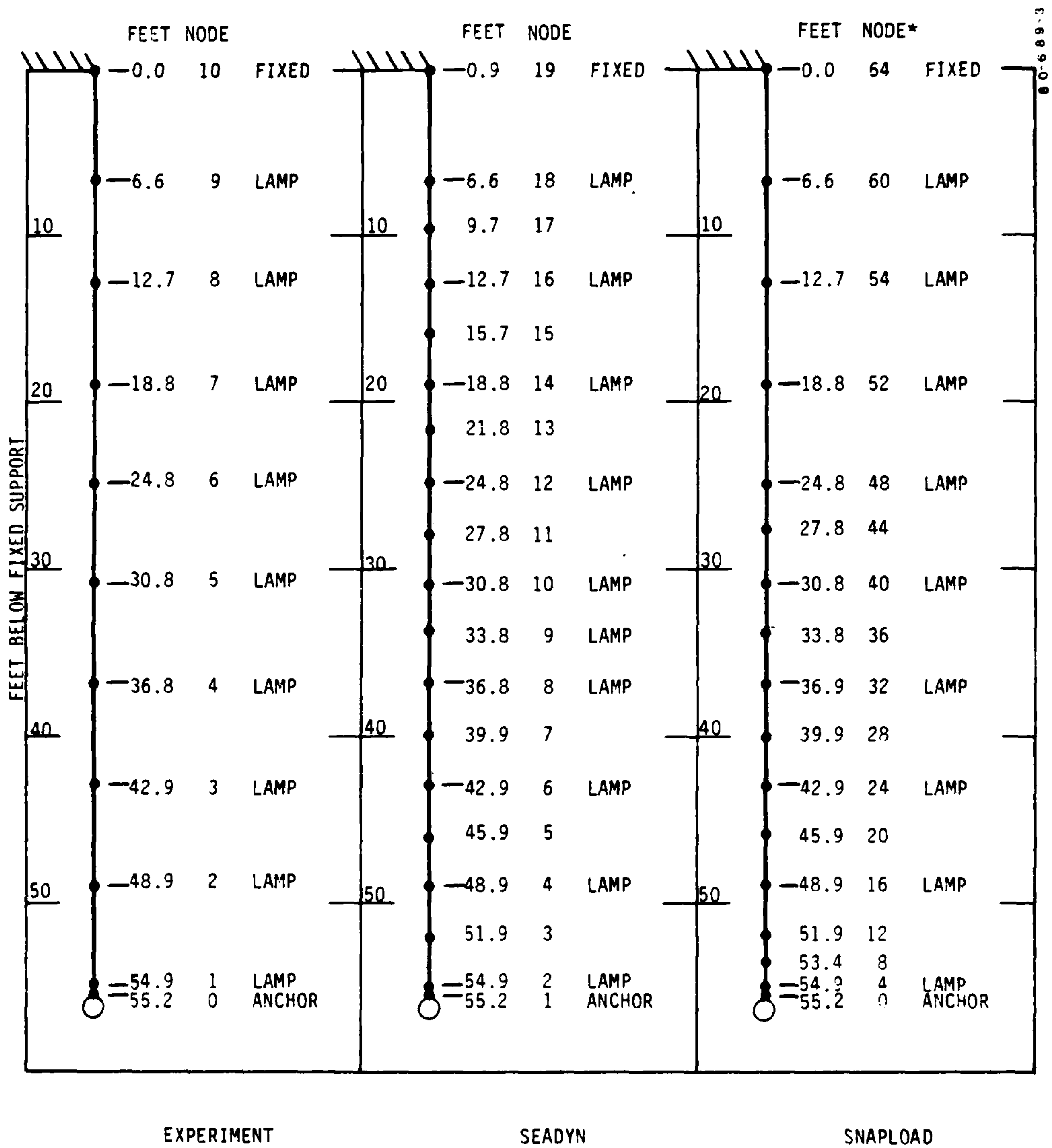
* SNAPLOAD NODES ARE COUNTED BY 4. THIS MODEL HAS 17 NODES.

Figure 3-1. Node Assignments for Run 6



* SNAPLOAD NODES ARE COUNTED BY 4. THIS MODEL HAS 9 NODES

Figure 3-2. Node Assignments for Run 11



* SNAPLOAD NODES ARE COUNTED BY 4. THIS MODEL HAS 17 NODES

Figure 3-3. Node Assignments for Run 15

SECTION IV
COMPARISON OF MODEL RESULTS AND EXPERIMENT DATA

4.1 GENERAL.

The two models, SEADYN and SNAPLOAD, are compared to the data from each of the three runs in three ways. First, the cable shape in a vertical plane is plotted for a sequence of instants during the run. "Snapshot" plots are the easiest to comprehend, because they show the experiment as the observer would see it: a sequence of shapes. Snapshot plots show whether the magnitude of dynamic forces are correctly modeled. Each part of the cable must follow its trajectory with the correct acceleration and velocity in order to maintain accurate shapes at subsequent times.

The second basis for evaluating the models is to compare the trajectories of selected points on the cable with the trajectories measured for those points. Trajectory plots show whether the direction of dynamic force during the run is modeled correctly. If the dynamic force is misaligned, a particle is accelerated into an improper trajectory.

The third portrayal compares the tension measured at the fixed end, plotted as a function of time during the run, with the corresponding calculated values.

4.2 RUN 6.

Run 6 is an anchor-last deployment simulation with the cable initially hanging in a deep catenary. Figure 4-1 is a snapshot plot of the SEADYN model with the data from Run 6. Figure 4-2 is the corresponding SNAPLOAD plot. The lamp at the fourth node from the fixed end did not operate during Run 6.

The initial node locations computed by SEADYN are in close agreement with the experimental data, but the initial static shape computed by SNAPLOAD is in substantial error. Two nodes near the vertex are so far from their correct locations that the curvature of the cable is reversed. Both points are at or near the region of maximum curvature, where the error required to reverse the curvature is greatest.

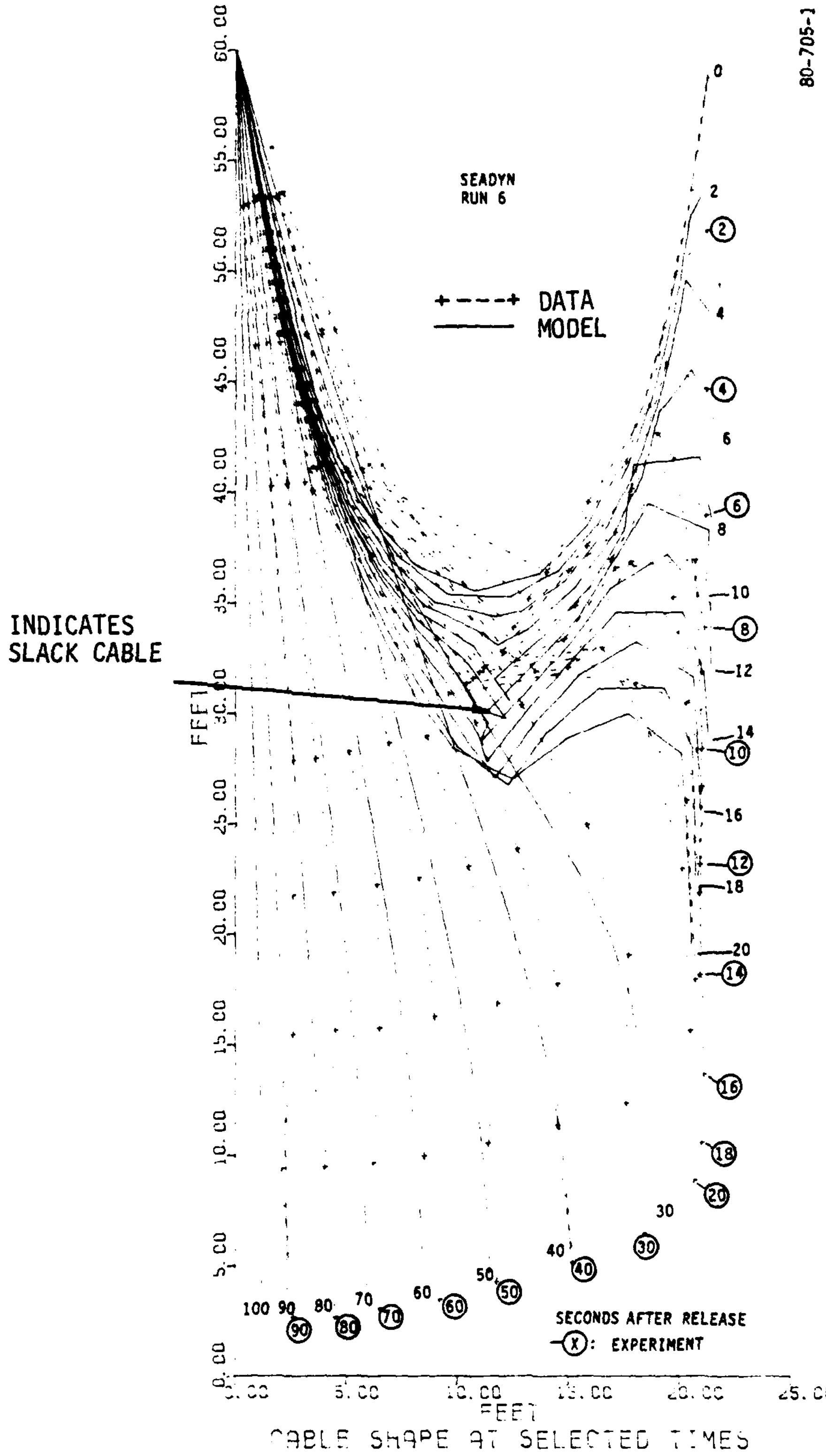


Figure 4-1. SEADYN Snapshots of Run 6

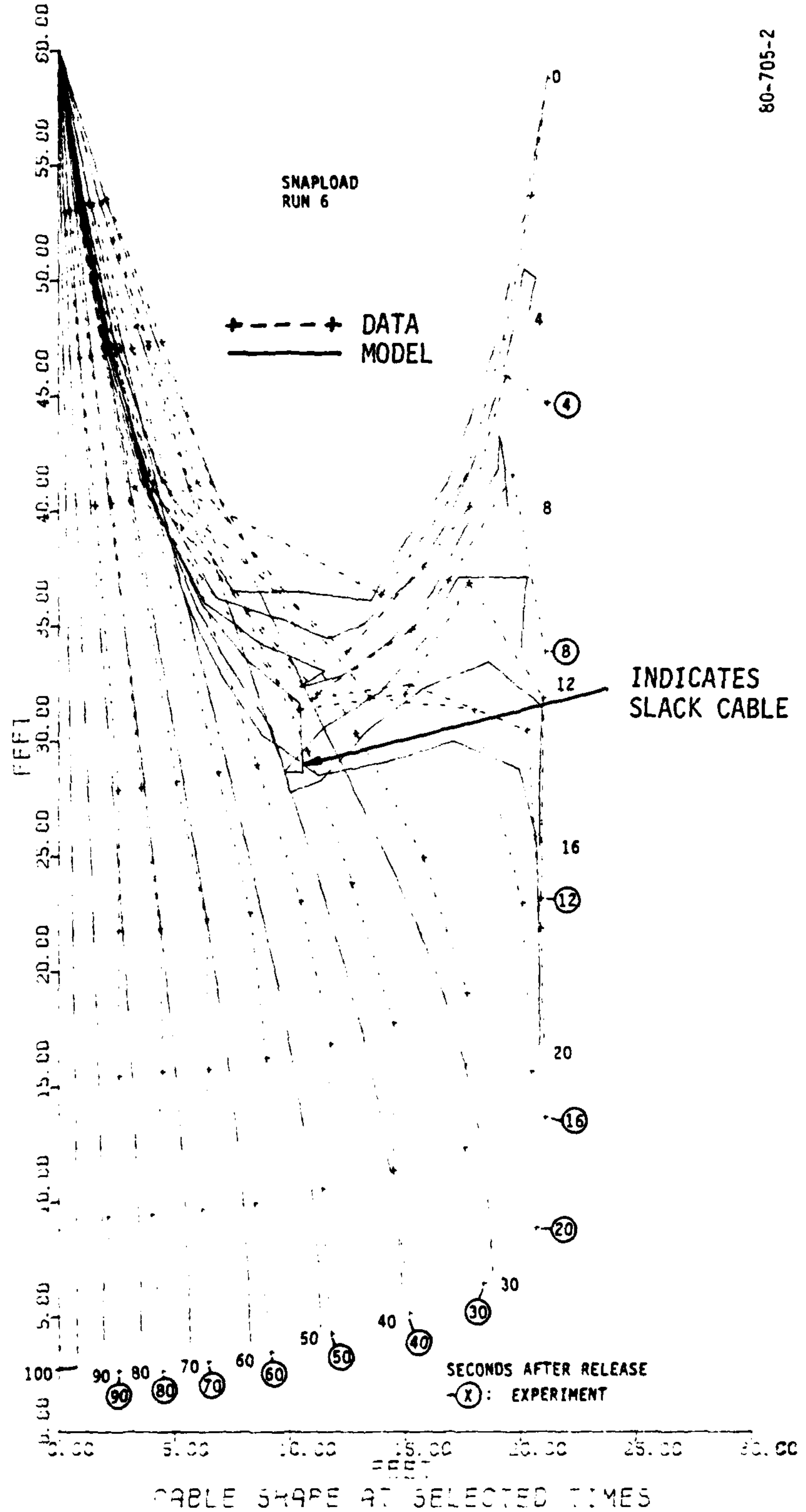


Figure 4-2. SNAPLOAD Snapshots of Run 6

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Both plots show the extreme curvature of the cable as it inverts the catenary while being dragged down by the anchor. Both models produce corresponding shapes. This stage ends when the cable come taut about 20 seconds after the release of the anchor. Both SEADYN and SNAPLOAD lag behind the data during the first 20 seconds. SEADYN places the anchor at t = 20 seconds, about where it was at t = 13.5 seconds - a time lag of about 6.5 seconds. SNAPLOAD shows a similar time lag, but only about five seconds. Both models "catch up" to the data by 40 seconds after release. Both models show erratic cable motion at the vertex of the catenary in the interval from 10 to 16 seconds after release, indicating slack cable.

In the second stage of the run, in which the anchor is suspended from the taut cable and swings toward the fixed support, SEADYN and SNAPLOAD calculate the velocity of the anchor node to be slightly faster than that experienced in Run 6. By t = 40 seconds, the lag of the first stage has been canceled.

The model calculations lead the measured locations during the second stage of Run 6, especially for the portion of cable 30 to 50 feet from the fixed end. SNAPLOAD leads the data somewhat more than SEADYN on the average, even though the largest SNAPLOAD lead, 11 seconds, is only a little more than the maximum 10 second SEADYN lead.

Figures 4-3 and 4-4 show the trajectories calculated by SEADYN and SNAPLOAD plotted with the measured trajectories. The trajectories during stage two, when the anchor is suspended from the cable, are essentially circular arcs about the fixed point. Both models meet this simple criterion. SEADYN does not allow the silicone cord to stretch quite enough. This is attributable to the input parameters more than the computer model.

The most obvious discrepancies between the models and the data on the trajectory plots for Run 6 occur along the three nodes nearest the anchor node during stage one (anchor descent). Without support at the anchor end, these nodes fall down and away from the anchor path. A little later, after the anchor has passed by, the cable gets tighter and the nodes are jerked back towards the anchor path. The models allowed too much time for the anchor descent. This extra time allowed the nodes to deflect further before tha anchor pulled them back.

The measured trajectory of the anchor is virtually a vertical fall until the cable snaps taut. But SEADYN shows the anchor oscillating slightly from side to side as it falls*. SNAPLOAD, on the other hand, calculates an anchor trajectory as much as 2.5 feet inside the measured path. This is sufficient to infer that the resulant force acting on the anchor calculated by SNAPLOAD is substantially misaligned.

Figures 4-5 and 4-6 show the tension at the fixed node as calculated by SEADYN and SNAPLOAD compared to the recorded values. The data record begins with the static value (.06 pound) which drops slightly when the tension wave from the anchor release arrives. There is a slight steady growth as support for the weight of the lower half-cable shifts to the fixed node. Then the tension abruptly increases as the cable straightens, comes taut, and stretches to stop the plummeting anchor. This abrupt rise is damped smoothly into the steady value that represents the immersed weight of the cable and anchor.

The tension values calculated by SEADYN and plotted on Figure 4-5 follow the general trend of the recorded tension. However, large oscillations are calculated during stage one. They are attributed to inadequate dissipation of

---

* These oscillations are an example of the interaction of the user with the model. The node spacing used to model these cases is about ten percent of the cable length; the radius of the "gooseneck" that forms behind the anchor is somewhat less. In reality, only a small part of the cable is passing around the gooseneck at any time, and the motion is smooth. In the model with large elements, however, the motion is exaggerated and irregular as the links articulate around the sharp bend. The angular speed rises to a peak and falls back for each element. The resulting centrifugal force, which acts on the entire element, therefore oscillates exaggeratedly; its vertical component is restrained and results in negligible displacement, but its horizontal component produces the anomaly in the anchor trajectory. The user must evaluate his input model in view of the results.

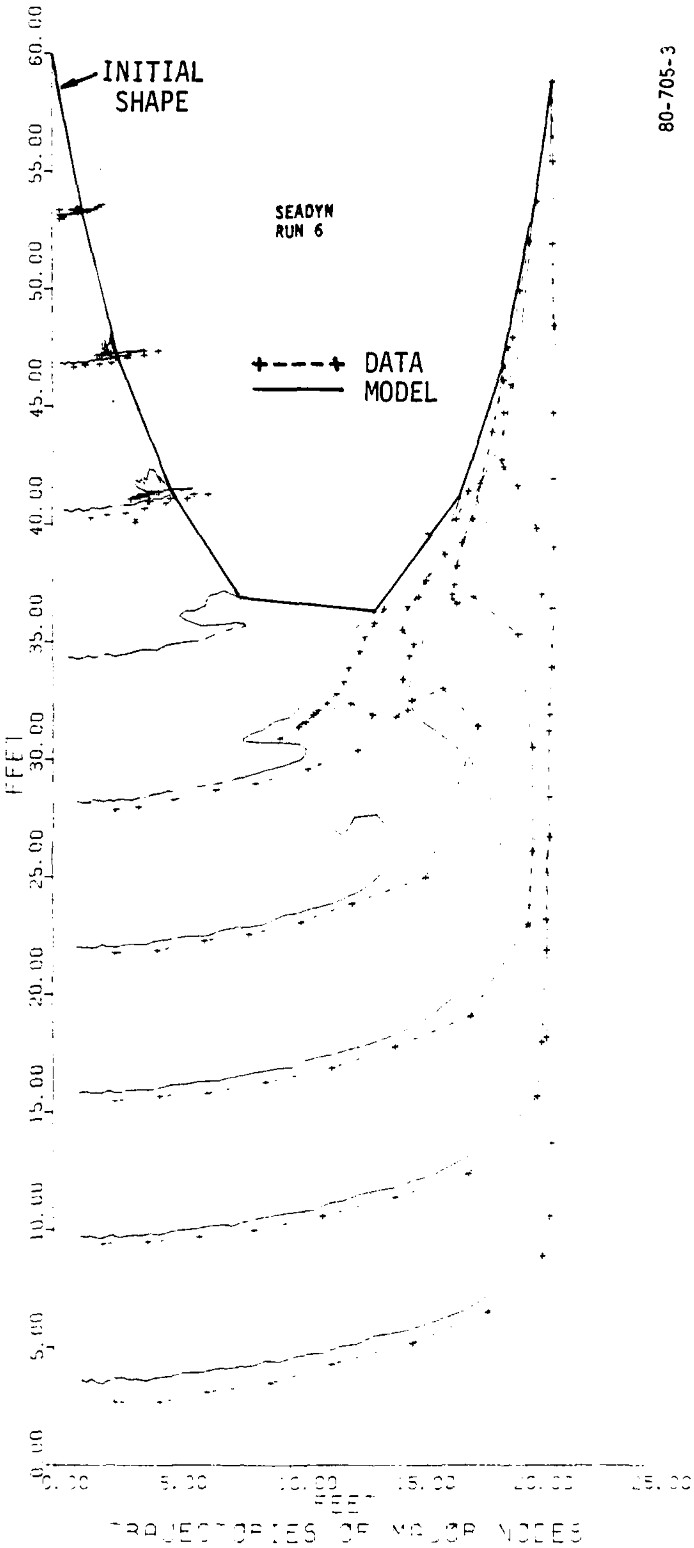

Figure 4-3. SEADYN Trajectories for Run 6

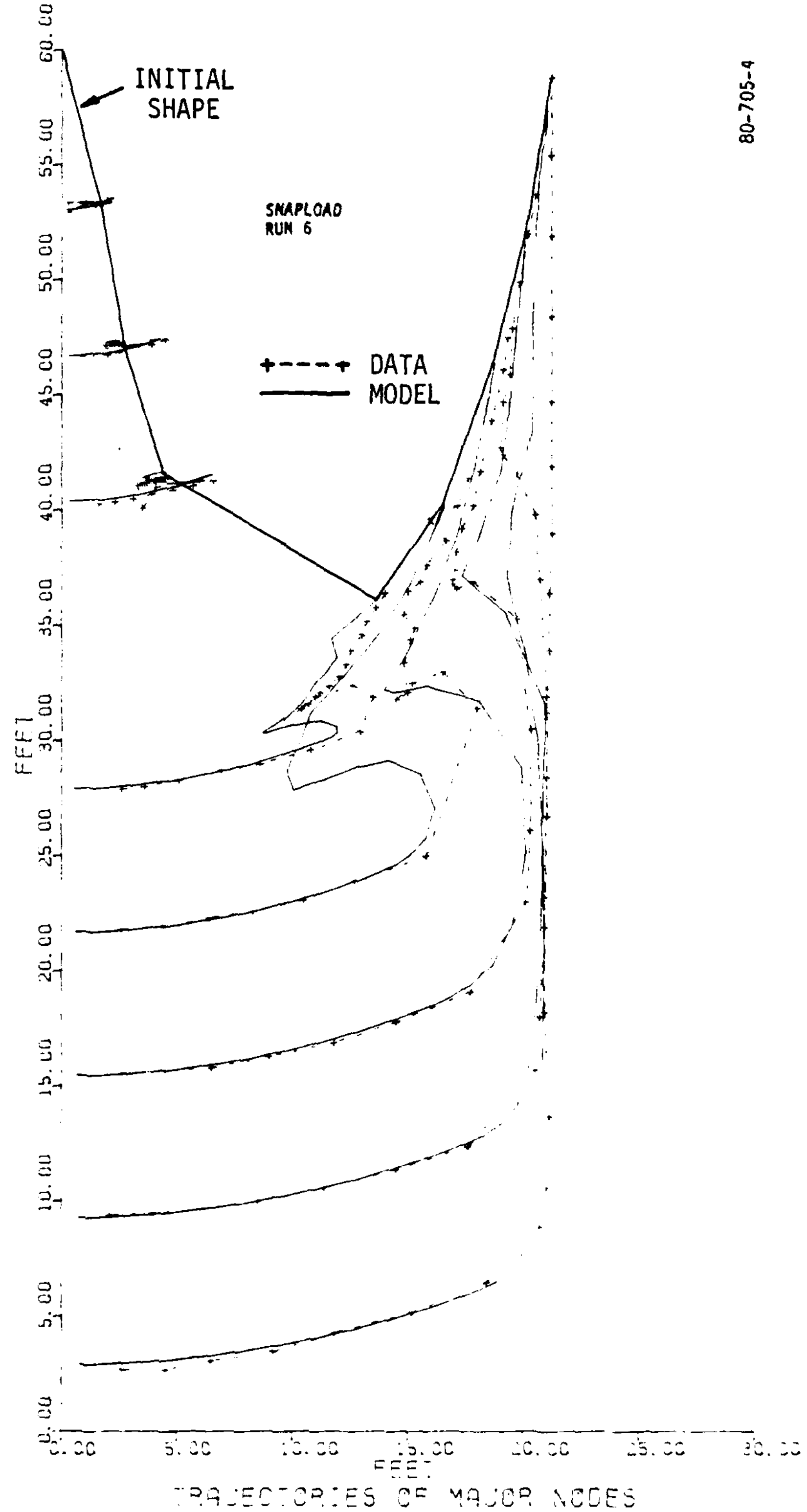

Figure 4-4. SNAPLOAD Trajectories for Run 6

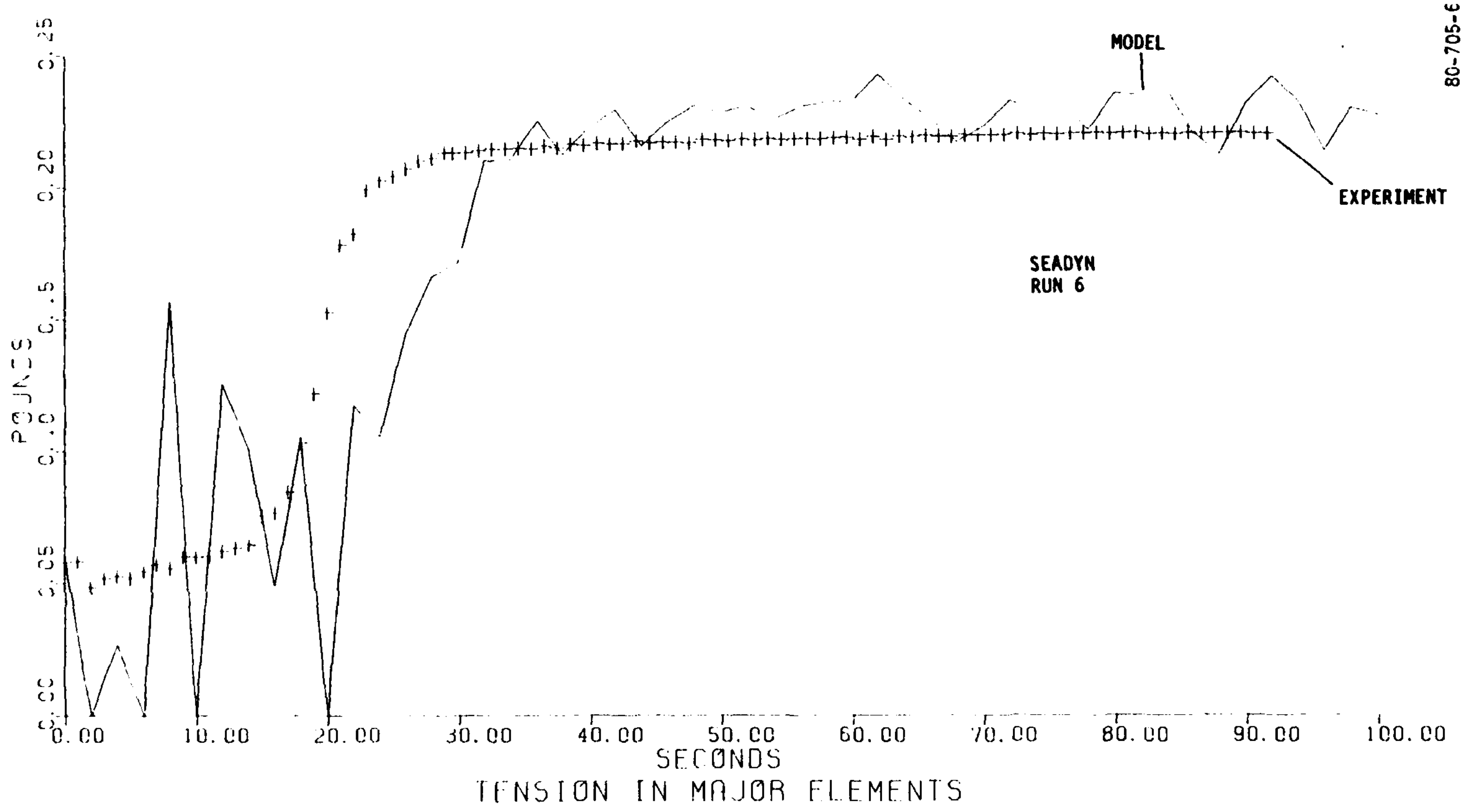

Figure 4-5. SEADYN Tension History During Run 6

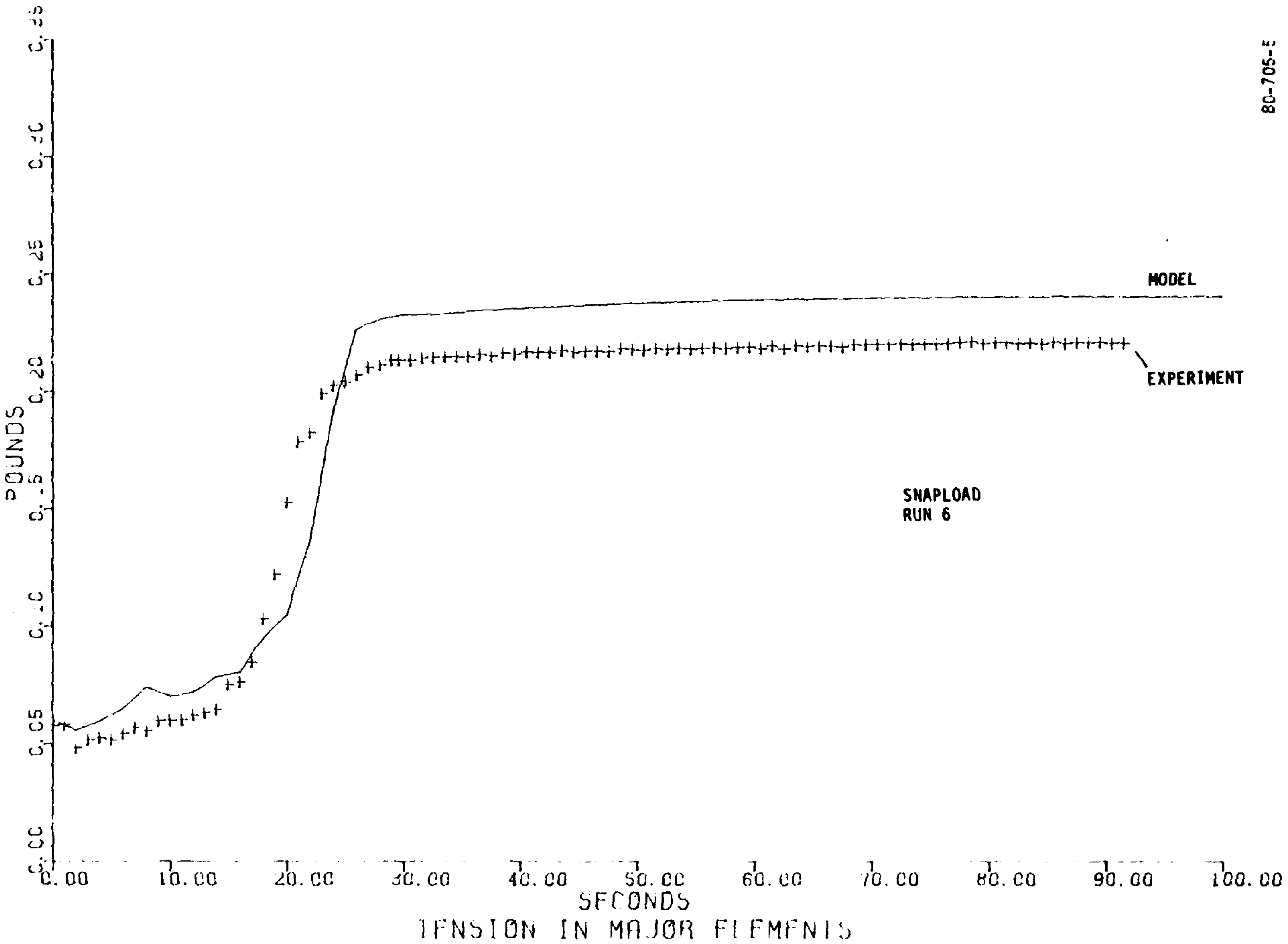

Figure 4-6. SNAPLOAD Tension History During Run 6

elastic energy in SEADYN because the model did not provide material damping. The rise in tension is about 6.5 seconds late, corresponding to the lag noted on the snapshot plot. The final equilibrium tension is higher than the measured value, and still retains spurious oscillations. SEADYN depends on measured values for the immersed weight of the anchor and cables. The discrepancy between the steady values on Figure 4-5 says more about the accuracy of the tensiometer used in the experiment vis-a-vis the scales used to weigh the anchor and cable.

4.3 RUN 11.

Run 11 is a buoy deflection experiment. The buoy is displaced to one side of the fixed anchorage, then released. It bobs up and drifts towards a position directly above the fixed anchorage. Figures 4-7 and 4-8 are the SEADYN and SNAPLOAD snapshot plots for Run 11, respectively. This experiment is hydrodynamically identical to stage two of Run 6, with the exception of the inversion of the hydrostatic force on the cable. As in Run 6, both computer models lead the data. By the end of the run, SEADYN is roughly 11 seconds ahead, while SNAPLOAD is about 15 seconds ahead.

The measured data present an anomaly at the start of the run that will be shown more clearly on the trajectory plots: upon release, the anchor bobs up, as expected, but jumps away from the fixed point. This suggests that the release mechanism perturbed the buoy.

Figures 4-9 and 4-10 are the trajectory plots for Run 11. They show clearly the anomalous motion of the buoy at the start of the run. Otherwise, the node trajectories are a smooth progression from the initial point to the final point. Both SNAPLOAD and SEADYN calculate a final, vertical shape in close agreement with the calculated static results presented in Section II.

Figures 4-11 and 4-12 show the SEADYN and SNAPLOAD comparisons to the measured fixed-end tension. Both models show the tension rising abruptly immediately upon buoy release. The data show a 2 second delay before the tension rises. Both models converge to a value of tension consistent with the measured weight and buoyancy of the components as provided in the input data for the models. SNAPLOAD shows the tension reading its final value within 15 seconds. The plot of the SEADYN results more nearly approximates an asymptomatic solution, although the curve is irregular from about 15 seconds through 30 seconds in the run, probably due to the inadequately damped "ringing" of the anchor shock as the line came taut.

4.4 RUN 15.

The snapshot plots for SEADYN and SNAPLOAD are presented as Figures 4-13 and 4-14. Both models show the anchor falling more slowly than measured in the experiment similar to their results for Run 6. As in Run 6, the models overtake the experiment during the pendulum stage. The anchor used in Run 15 was heavier than the anchor for Run 6. Less time is available for slack cable to develop at the vertex, and both models, as well as the data, reflect the smoother descent. This is also apparent in the trajectory plots (Figures 4-15 and 4-16) for SEADYN and SNAPLOAD.

The fixed-end tension plots on Figures 4-17 and 4-18 show that both models and the data converged to the immersed weight of the anchor and line with good accuracy. SEADYN gives somewhat erratic values, as in the other cases. SEADYN calculated the time for the anchor to jerk the cord taut about 5 seconds late; SNAPLOAD was about 1.5 to 2 seconds late.

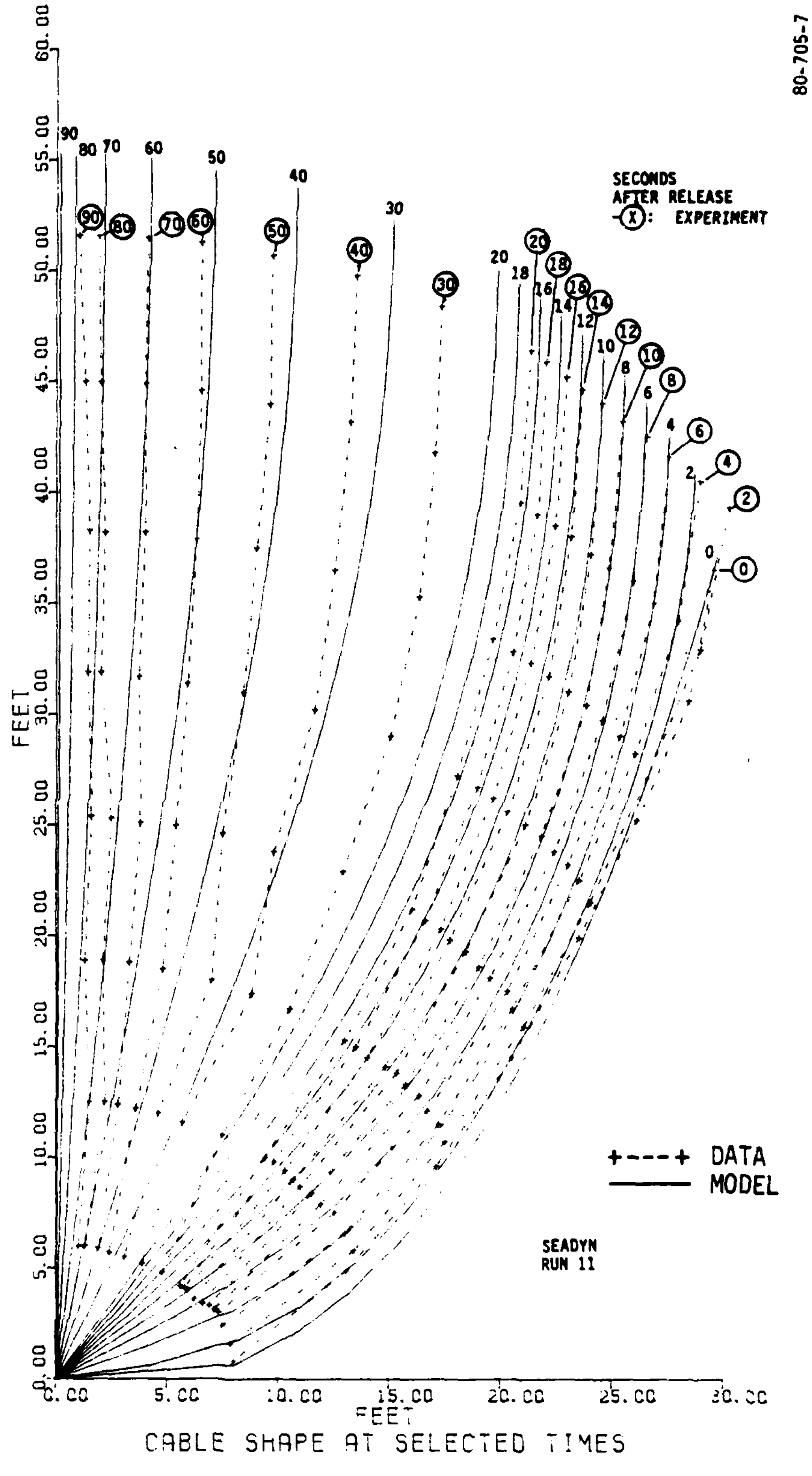

Figure 4-7. SEADYN Snapshots of Run 11

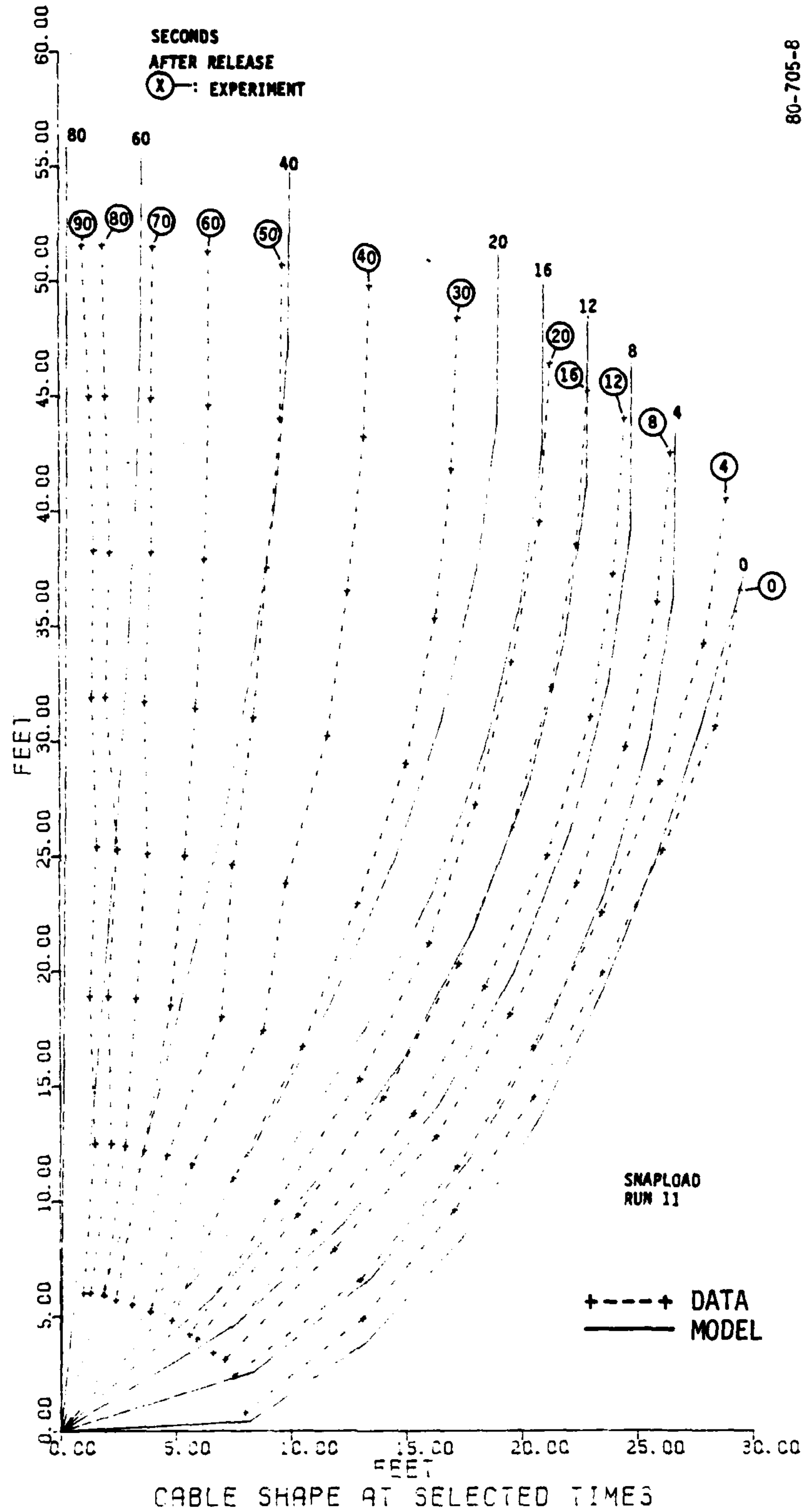

Figure 4-8. SNAPLOAD Snapshots of Run 11

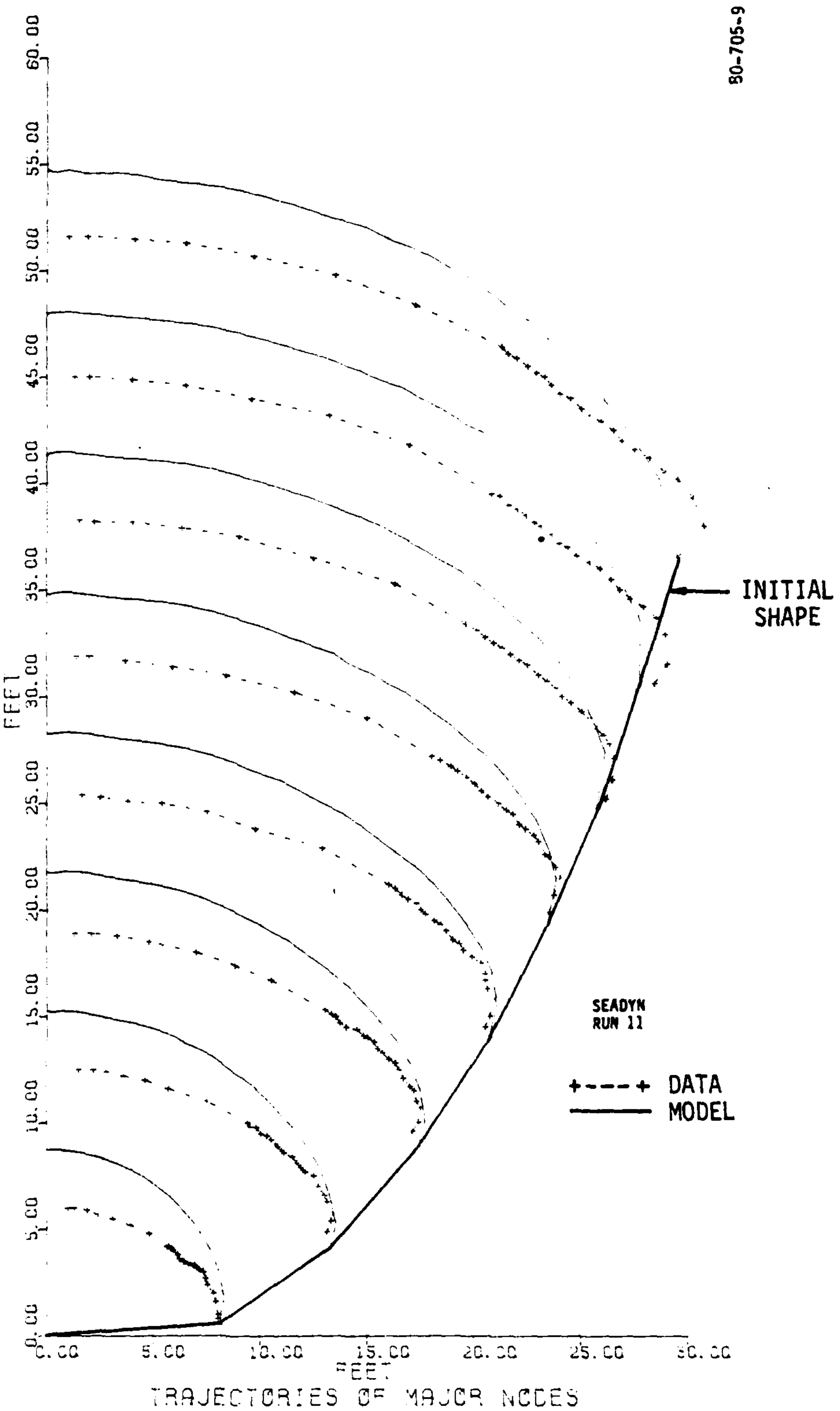

Figure 4-9. SEADYN Trajectories for Run 11

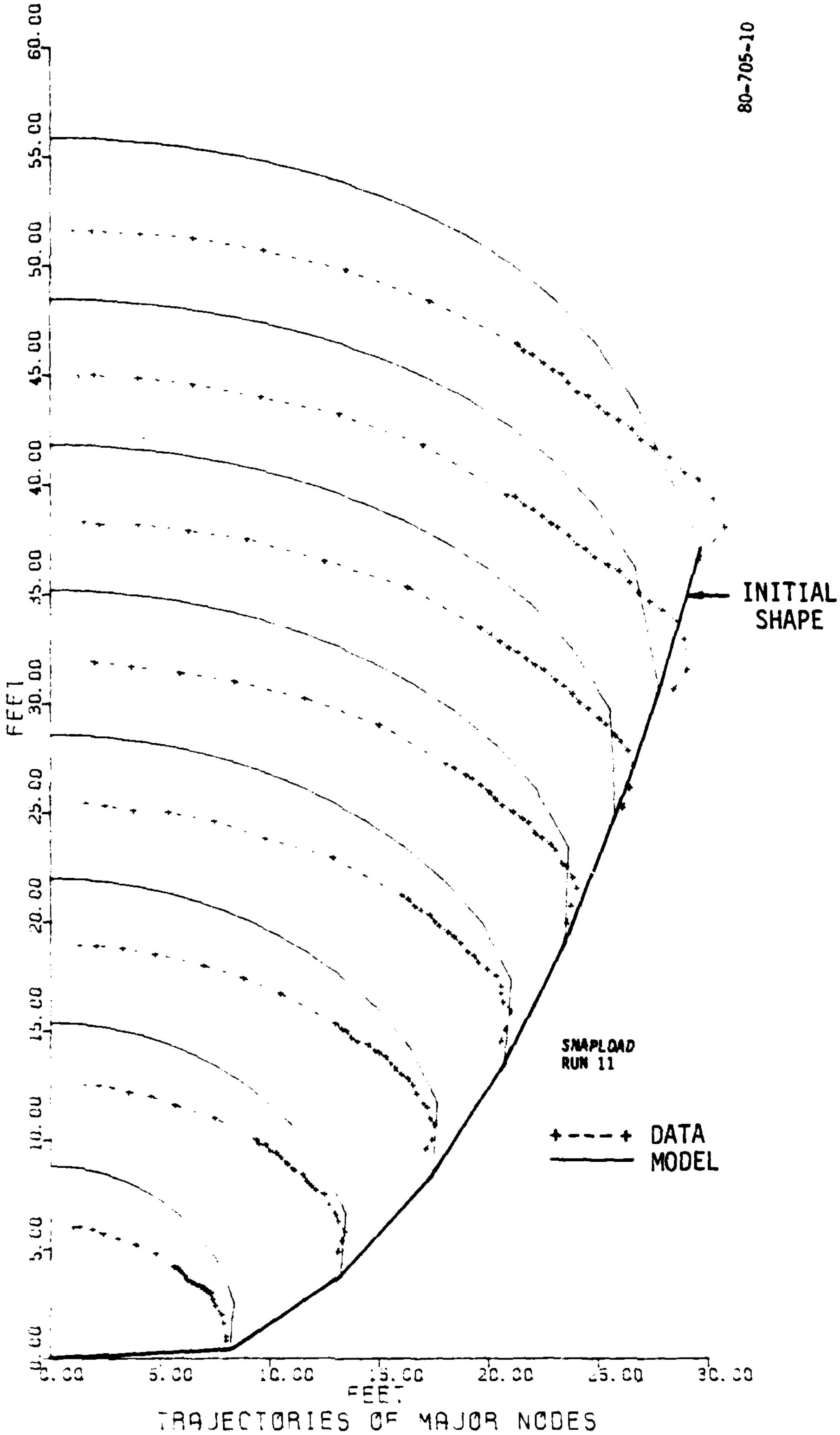

Figure 4-10. SNAPLOAD Trajectories for Run 11

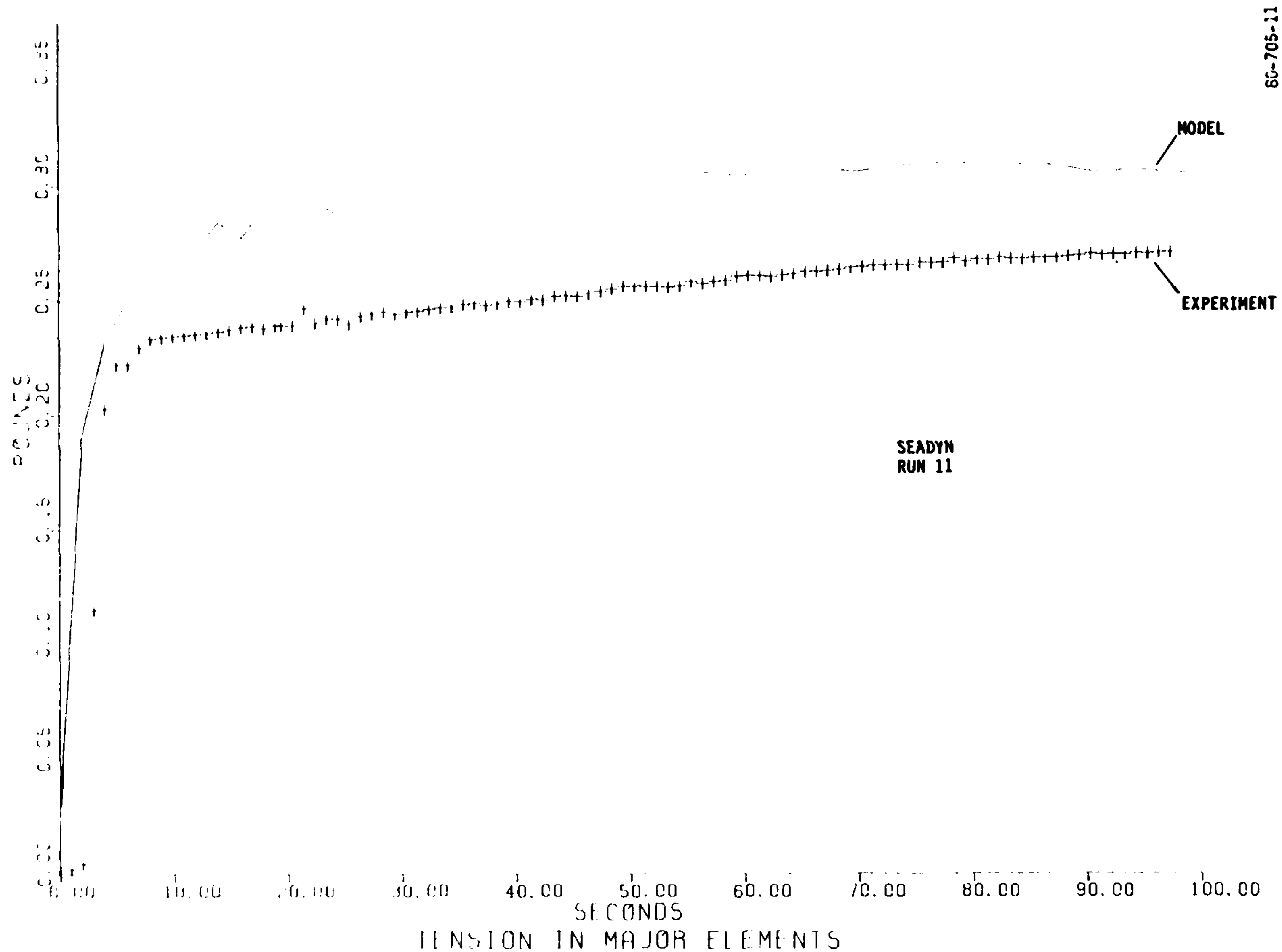

Figure 4-11. SEADYN Tension History During Run 11

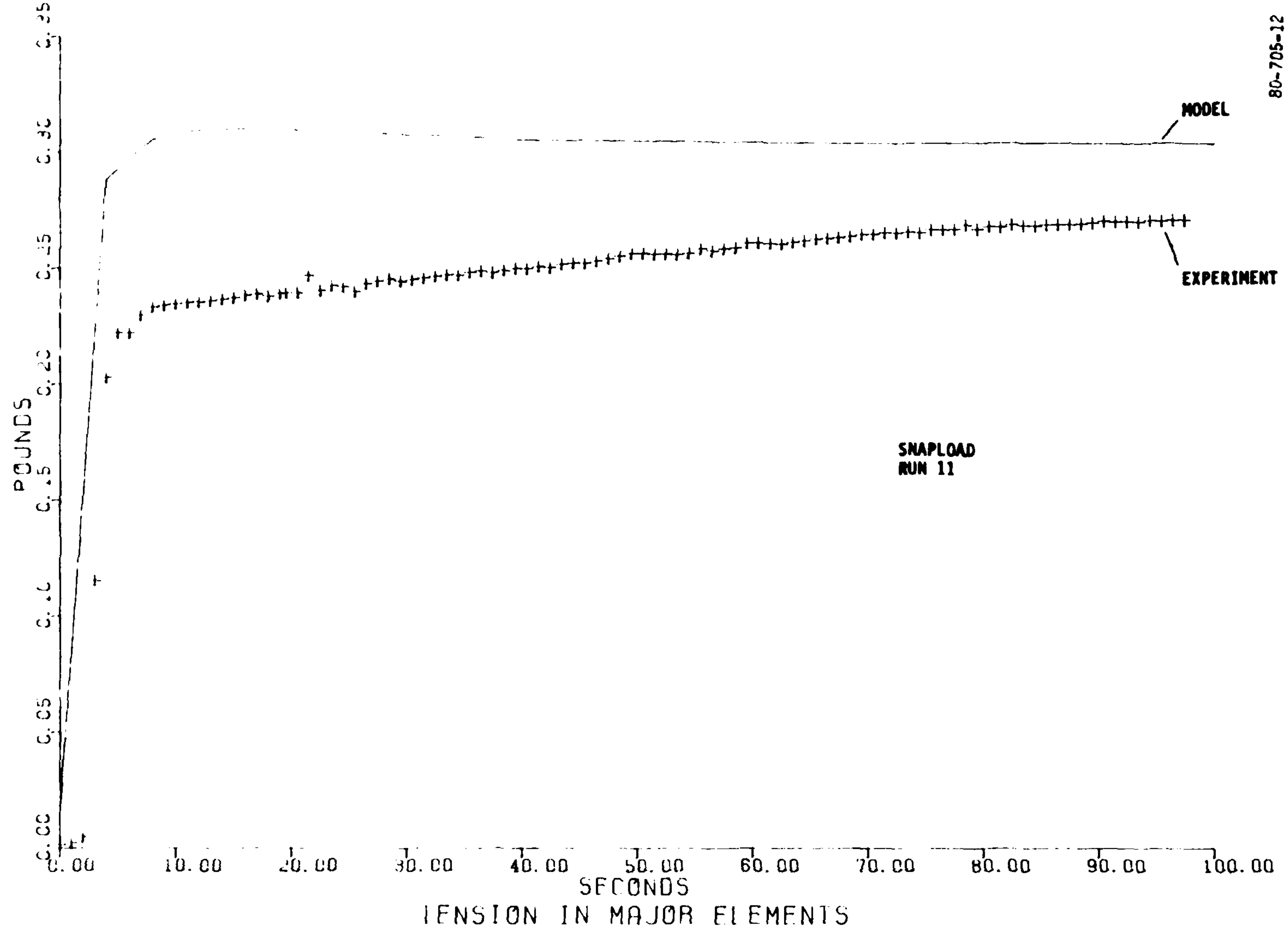

Figure 4-12. SNAPLOAD Tension History During Run 11

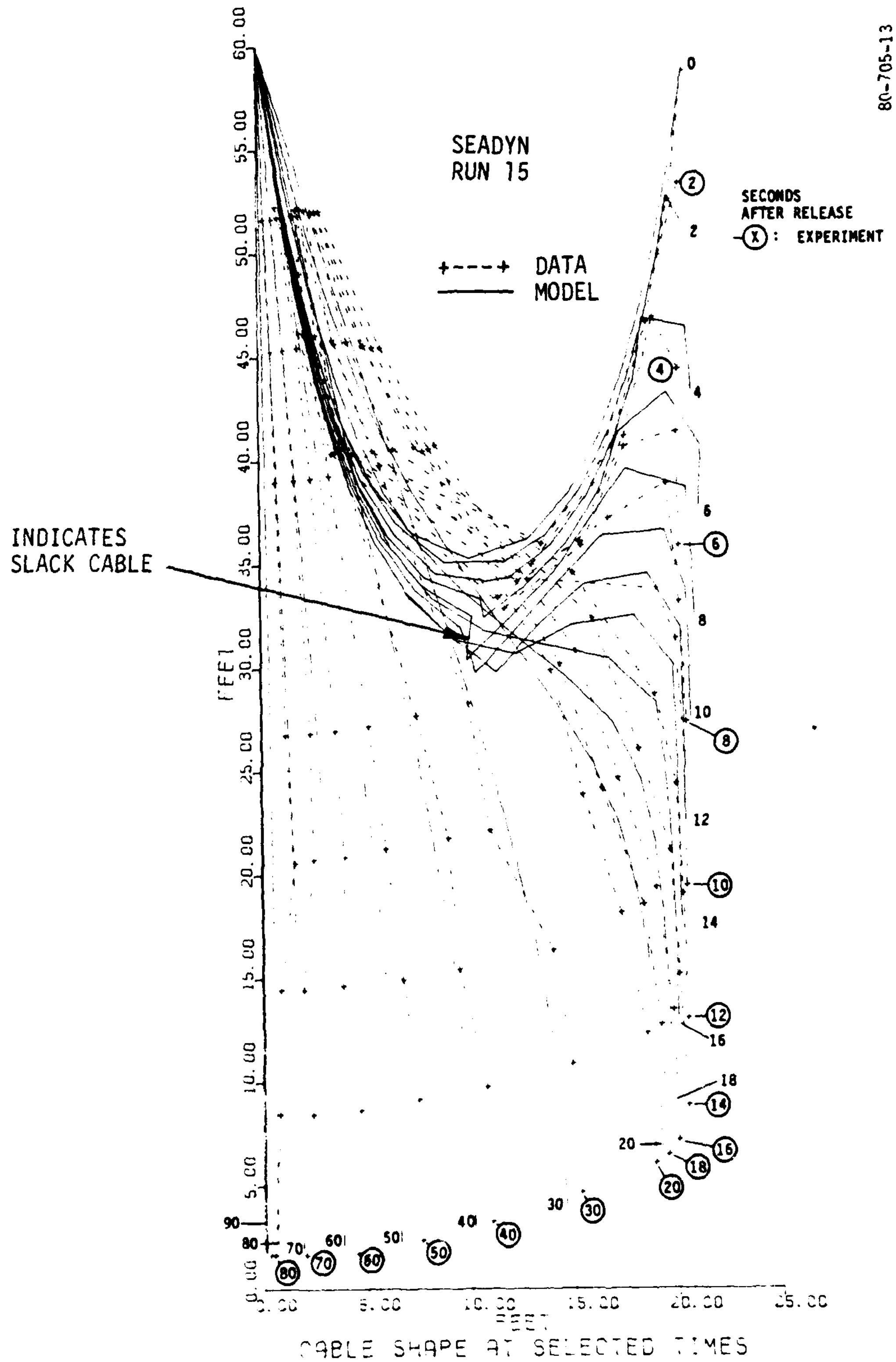

Figure 4-13. SEADYN Snapshots of Run 15

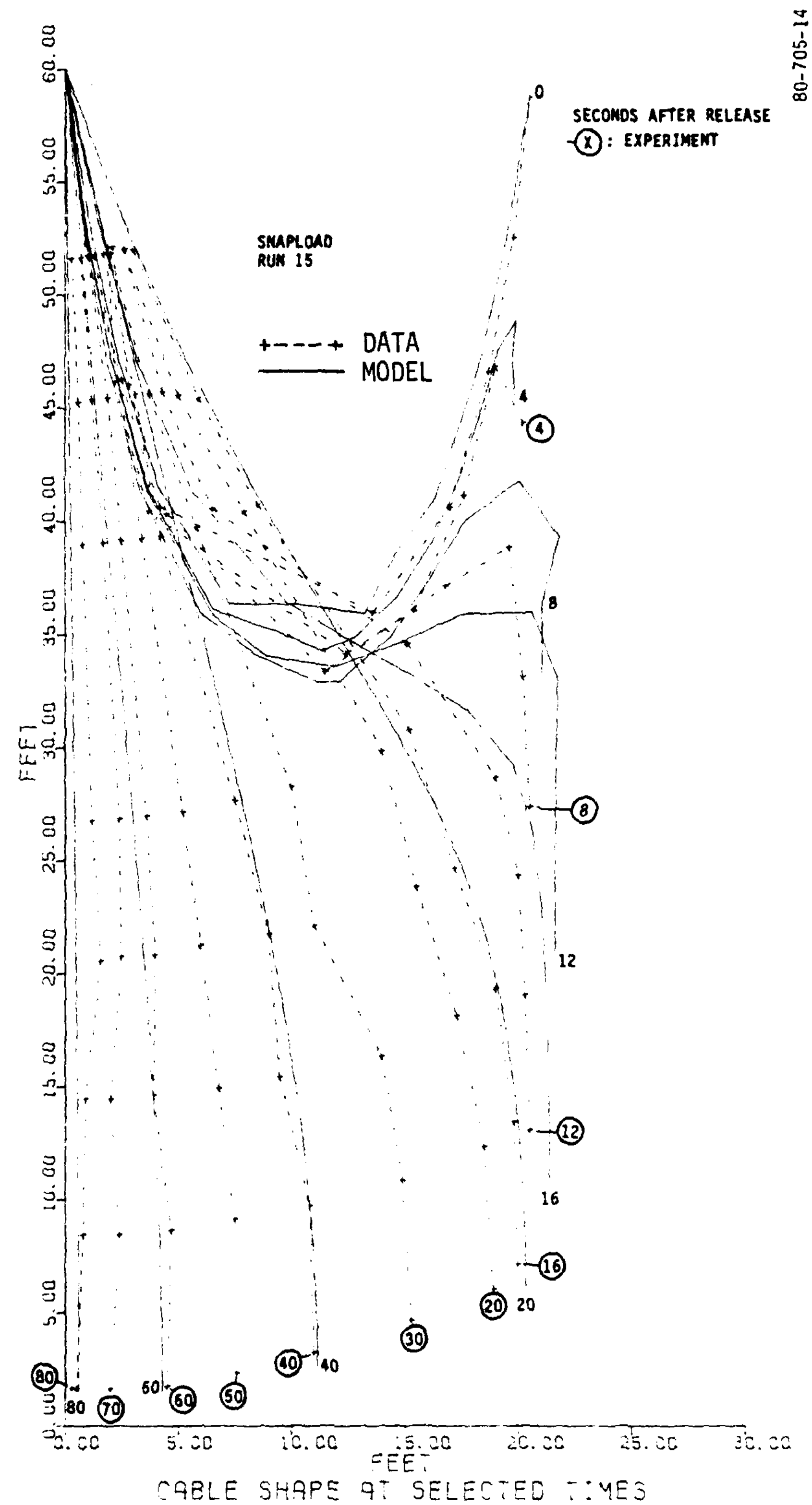

Figure 4-14. SNAPLOAD Snapshots of Run 15

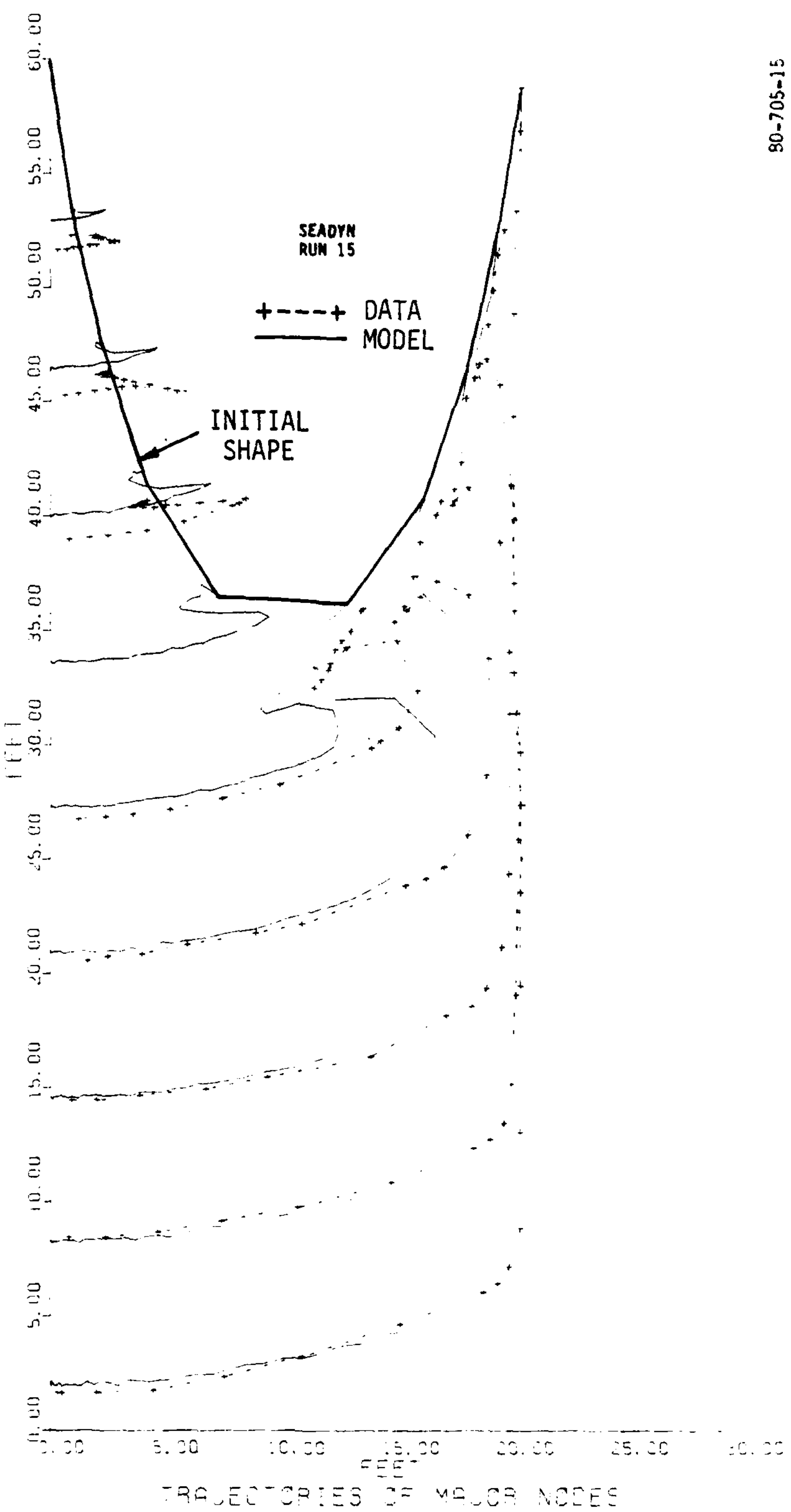

Figure 4-15. SEADYN Trajectories for Run 15

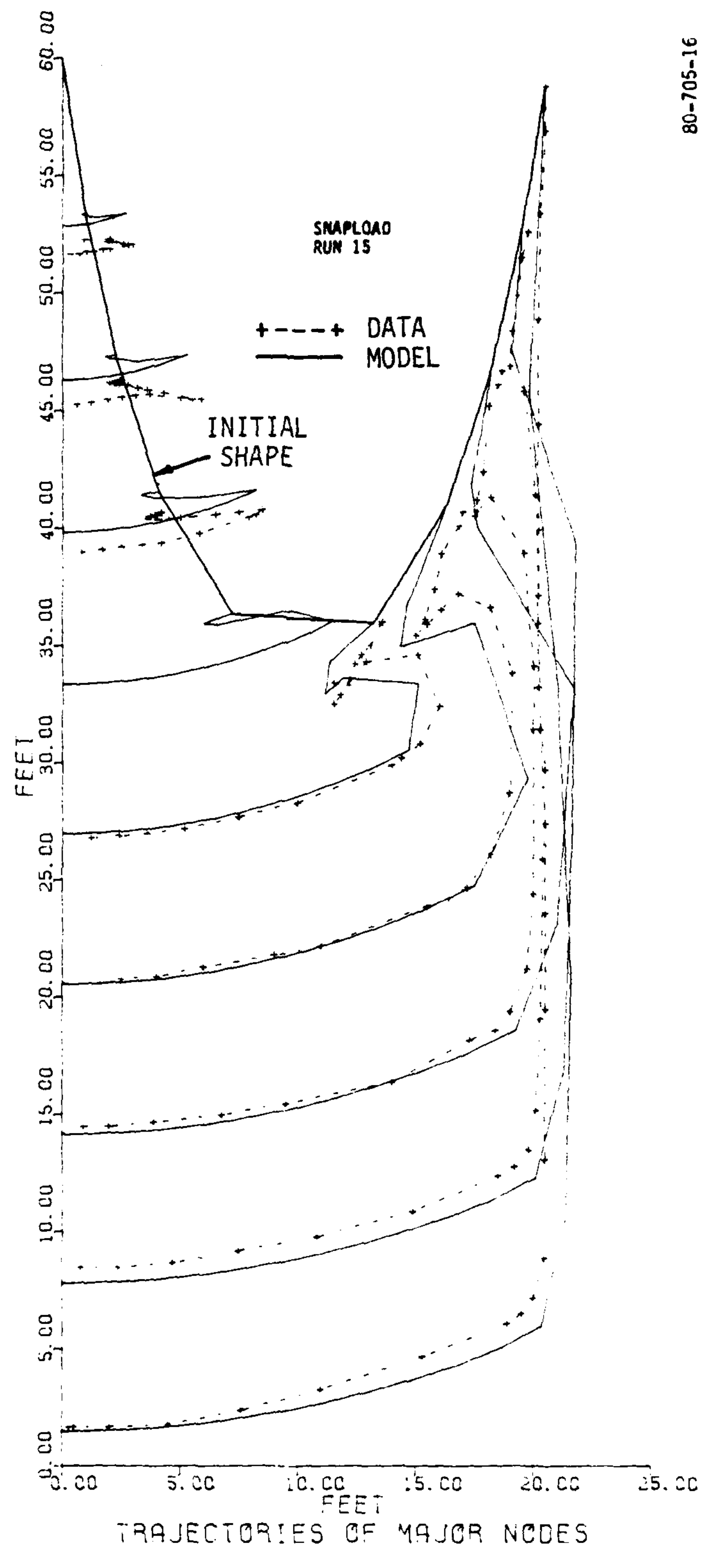

Figure 4-16. SNAPLOAD Trajectories for Run 15

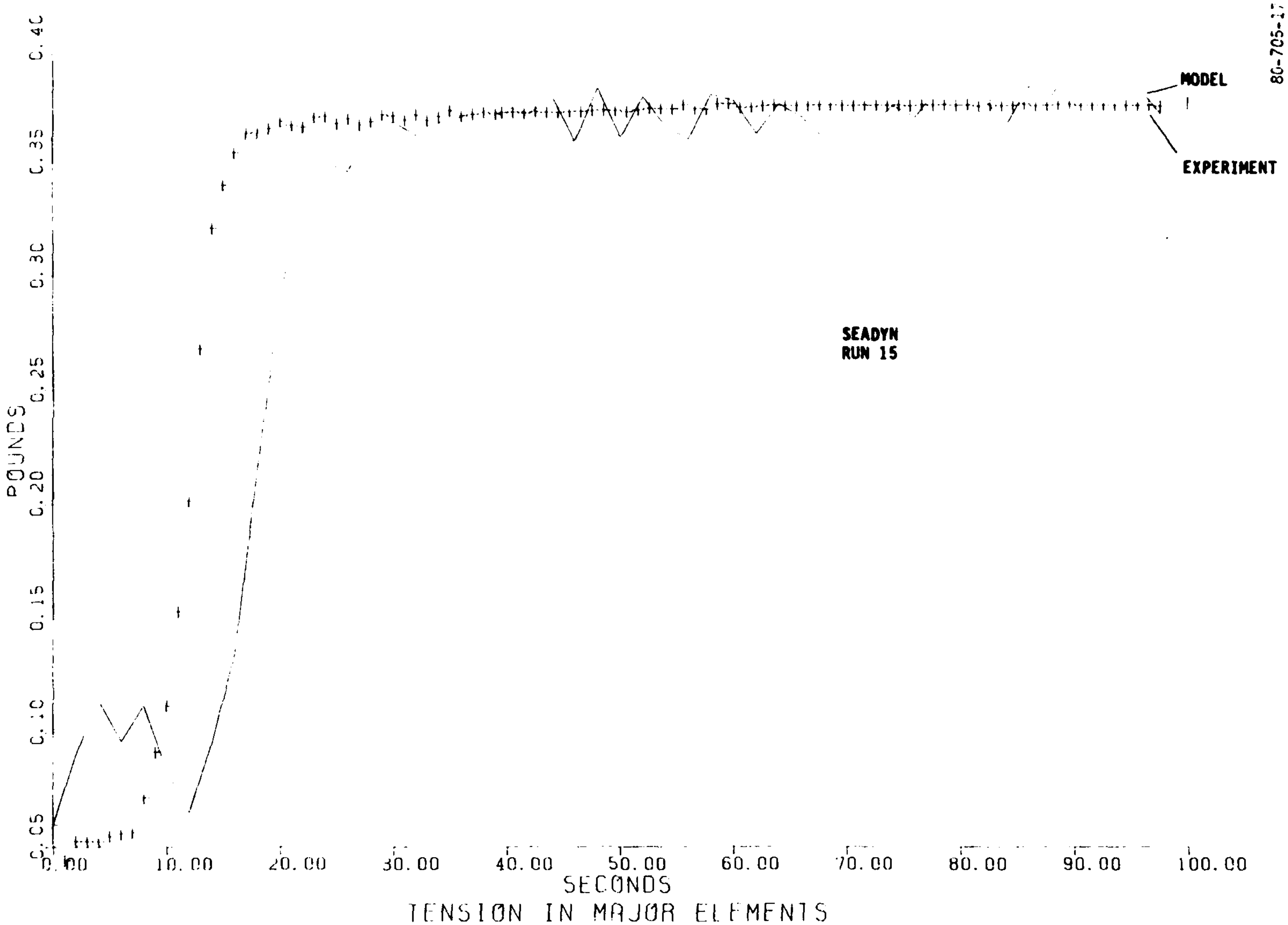

Figure 4-17. SEADYN Tension History During Run 15

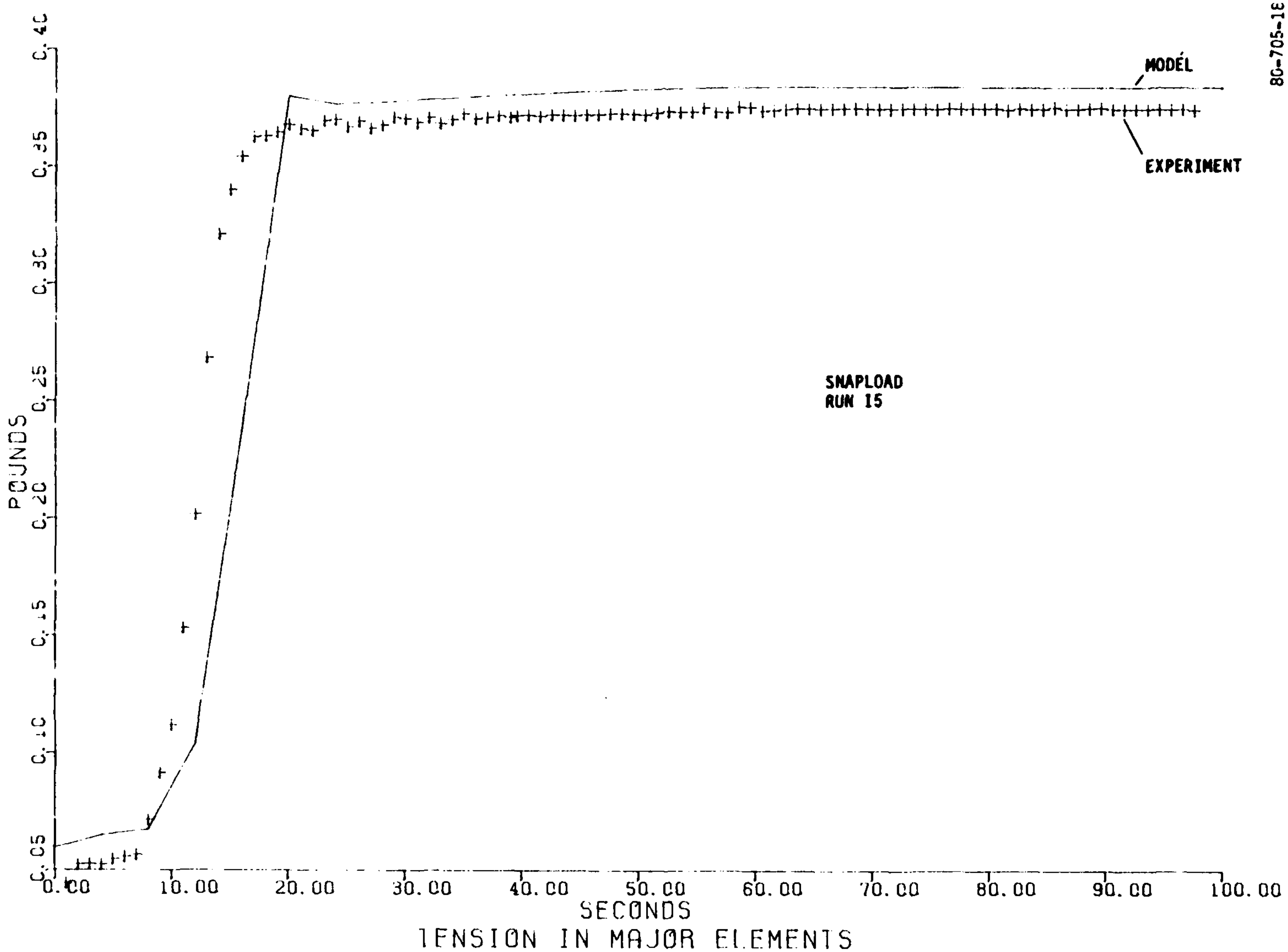

Figure 4-18. SNAPLOAD Tension History During Run 15

SECTION V
CONCLUSIONS

Comparisons of the measured static configuration of the 60-foot cable for the start and end of Runs 6, 11, and 15 to equivalent values calculated from the elastic catenary equations show that the experimental technique could measure the position of a cable point to within about a foot. Runs 6 and 15 had a mean error of 8 inches and a standard deviation of 6 inches. Tensions of a few tenths of a pound were measured within a few thousandths of a pound. The data in Run 11 are not as reliable as for the other runs, because the position data may have been digitized incorrectly.

Both models succeeded in reproducing all the salient features of each run. SEADYN determined the initial catenary accurately, even though the nodes were input as a horizontal (Runs 6 and 15), or vertical (Run 11) line for convenience. SNAPLOAD requires a close approximation of the initial catenary as input data.

Both SEADYN and SNAPLOAD converged on a final, vertical equilibrium shape that agrees closely with the stretched length for a vertical elastic catenary. With both models, however, several attempts were required to find the right operating parameters to solve the problem in a single computer run.

Both models computed the overall time required for each event to within a few percent of the elapsed time of the experiment, but they tended to lag or lead the data for various parts of each event.

Slack cable occurred briefly near the vertex of the catenaries of the anchor-drop cases shortly after the anchor was released. Both SEADYN and SNAPLOAD models detected the start and end of the slack cable interval. At the other extreme, both models calculated the duration of the anchor impact load correctly, as well as the change in tension produced by the impact. The simulated anchor impact was several seconds late for each model, because the models computed a slow value for the anchor descent speed.

The anchor-drop cases represent a difficult trial of a cable dynamics model, because they combine sharp, reversed curvature, and low tension with an impact load. It is worth noting, therefore, that the models successfully "ran" these cases from start to finish without numerical instability.

The comparisons did reveal some weaknesses in the models, some of which have been mentioned already. The "handbook" drag coefficients provided by default in the model produced errors in the rate of dynamic processes. The drag coefficients for the anchors and buoy were too large; those for the cable were too small. The problem is aggravated in SEADYN, which must be recompiled with a new drag subroutine in order to use another value. The drag subroutine in SEADYN should be revised to give the user a small library of drag coefficient functions, for which the user provides arguments in the input data.

Both SEADYN and SNAPLOAD showed the anchor deflecting slightly away from the fixed vertical during the free-fall portion of the descent. The data show the anchor falling as expected: pulled slightly towards the fixed vertical by the cable drag.

Neither SEADYN nor SNAPLOAD included material damping in their simulations. SNAPLOAD substituted numerical damping to stabilize its computations, and this gave smooth tension variations, with no perceptible loss in accuracy. The SEADYN model would benefit substantially from the addition of material damping, since the tension results in these and other comparisons have been degraded by improperly damped oscillations. (This option is currently being added to SEADYN.)

The novice user of SEADYN may be overwhelmed by the variety of options and alternatives presented. As this model progresses towards more widespread use, it is important that obsolete options be deleted. Perhaps they could be retained, but references restricted to a separate Advanced Users' Manual. SNAPLOAD is simpler, but an awkward node-numbering scheme makes data entry prone to error and makes interpreting the results more difficult. A simple node number translator in the input and output stages would ease the problem without requiring a major revision of the code.

SEADYN and SNAPLOAD have successfully modeled dynamic cable events at scales of 6, 60, and 2,500 feet with verification from experimental data. Verification has included relatively easy buoy relaxation events, but also anchor-last deployment simulations, which are much more severe. The latter also have obvious practical application in mooring design. Although both models are valid for calculating anchor-last deployments, the restriction of SNAPLOAD to dynamics in a vertical plane will limit its wide acceptance. The more general model will have more opportunities for application and refinement. SEADYN, upgraded with material damping, a more robust technique of convergence, simplified data specification, and an improved system of drag coefficients, will be a useful mooring design tool.

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APPENDIX A

POSITION AND TENSION MEASUREMENTS

FOR

RUNS 6, 11, and 15

OF THE

CEL 60-FOOT MOORING DYNAMICS EXPERIMENT

APPENDIX A
POSITION AND TENSION MEASUREMENTS
FOR
RUNS 6, 11, AND 15
OF THE
CEL 60-FOOT MOORING DYNAMICS EXPERIMENT

Table A-1 is a list of the lamp positions for each of Runs 6, 11 and 15. The values were obtained by digitizing photographs of the lamp-flashes against a calibrated grid. The time of the flash is given in seconds after the mooring was released. The left column in each table, labeled "HOR", is the horizontal displacement (feet) of the lamp from the fixed end. The column labeled "Depth" is the distance (feet) of the lamp beneath the fixed point for Runs 6 and 15. For Run 11, the column is the distance of the lamp above the fixed end.

The tension data are summarized on Tables A-2, A-3, and A-4. Time is given in seconds after the release of the mooring. The output of the force meter is then given along 3 orthogonal axes. "HORIZ." refers to the horizontal axis lying in the vertical plane of the mooring. "UNUSED" refers to the horizontal axis normal to the vertical plane of the mooring. The "VERTICAL" component is positive downward in Runs 6 and 15, but positive upward in Run 11. "TENSION" is the vector sum of all three components. "PHI" is the angle from a horizontal plane to the tension vector, measured in a vertical plane. The angle "THETA" is measured between the vertical plane containing "PHI" and the nominal vertical plane of the mooring. "RADIAL" is the vector sum of the horizontal components, "HORIZ." and "UNUSED".

The conversion of the force gauge output in volts to engineering units in pounds was performed using a calibration matrix that corrected for "cross-talk" between the three channels.

TABLE A-1. CEL 60 FOOT EXPERIMENT: MEASURED LAMP POSITIONS FOR RUNS 6, 11, 15

TIME . . 0.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
1.00	6.65
2.50	12.75
4.50	18.65
14.00	23.65
17.60	18.65
19.30	12.55
20.50	6.35
21.20	1.25

TIME . . 1.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
1.00	6.65
2.50	12.75
4.40	18.65
13.60	24.25
17.10	19.85
19.10	13.95
20.20	8.05
21.20	4.65

TIME . . 2.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
1.00	6.65
2.40	12.75
4.30	18.65
13.20	24.85
15.90	20.45
18.60	16.15
19.80	10.15
21.20	8.15

TIME . . 3.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
1.00	6.65
2.40	12.75
4.20	18.65
13.00	25.45
16.60	21.35
18.10	18.35
19.50	12.15
21.20	11.65

TIME . . 0.00
RUN . . . 11

HOR.	DEPTH
29.50	36.50
28.40	30.60
26.10	25.20
23.50	19.90
20.50	14.50
17.10	9.60
13.10	4.90
8.00	.80
0.00	0.00

TIME . . 1.00
RUN . . . 11

HOR.	DEPTH
30.70	38.00
29.00	31.50
26.40	26.10
23.70	20.70
20.70	15.00
17.40	10.00
13.30	5.40
8.00	1.00
0.00	0.00

TIME . . 2.00
RUN . . . 11

HOR.	DEPTH
30.20	39.30
28.90	32.90
26.50	27.10
24.00	21.50
21.00	15.90
17.50	10.70
13.40	5.80
7.90	1.60
0.00	0.00

TIME . . 3.00
RUN . . . 11

HOR.	DEPTH
29.50	40.20
28.50	33.70
26.30	27.80
23.80	22.00
20.60	16.30
17.30	11.00
13.10	6.30
7.80	2.00
0.00	0.00

TIME . . 0.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
.90	7.75
2.50	13.75
4.20	19.35
13.60	24.05
17.00	19.35
18.70	13.35
19.80	7.45
20.50	1.25

TIME . . 1.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
2.00	7.75
2.40	13.75
4.10	19.35
13.50	24.15
16.80	19.95
18.50	13.95
19.50	8.55
20.50	3.15

TIME . . 2.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
2.00	7.75
2.30	13.75
4.00	19.45
13.10	25.05
16.10	21.15
18.10	14.85
19.30	10.15
20.30	6.65

TIME . . 3.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
1.90	7.85
2.30	13.85
3.90	19.45
12.70	25.45
15.80	22.65
17.90	17.65
19.10	11.65
20.20	11.15

TABLE A-1. (Continued)

TIME . . 4.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
1.00	6.65
2.30	12.75
4.10	18.75
12.50	26.15
15.80	22.45
17.80	19.85
19.40	14.15
21.20	15.35

TIME . . 5.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
.90	6.65
2.30	12.75
4.00	18.75
12.30	26.75
15.50	23.15
17.30	20.85
19.10	15.35
21.20	18.15

TIME . . 6.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
.90	6.65
2.20	12.75
3.90	18.75
12.00	27.25
15.00	23.55
17.10	21.85
19.00	17.35
21.20	21.05

TIME . . 7.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
.90	6.65
2.20	12.85
3.80	18.75
11.60	27.65
14.80	24.55
17.00	22.65
19.10	17.65
21.10	23.65

TIME . . 4.00
RUN . . . 11

HOR.	DEPTH
28.90	40.50
27.90	34.20
26.00	28.20
23.50	22.50
20.50	16.70
17.20	11.50
13.00	6.60
7.50	2.40
0.00	0.00

TIME . . 5.00
RUN . . . 11

HOR.	DEPTH
28.20	41.20
27.30	34.60
25.70	28.50
23.30	22.60
20.50	17.00
17.00	11.70
12.70	7.00
7.40	2.70
0.00	0.00

TIME . . 6.00
RUN . . . 11

HOR.	DEPTH
27.50	41.60
26.80	35.00
25.30	29.00
23.00	23.20
20.30	17.50
16.70	12.10
12.50	7.50
7.30	3.00
0.00	0.00

TIME . . 7.00
RUN . . . 11

HOR.	DEPTH
26.90	42.00
26.40	35.50
25.00	29.30
22.80	23.50
19.90	17.80
16.50	12.50
12.10	7.70
7.20	3.00
0.00	0.00

TIME . . 4.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
1.90	7.85
2.20	13.85
3.70	19.55
12.40	25.85
15.40	23.95
17.60	18.85
19.00	13.15
20.20	15.65

TIME . . 5.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
1.90	7.85
2.10	13.85
3.60	19.65
12.20	26.45
15.00	24.65
17.50	19.55
19.60	14.25
20.20	20.15

TIME . . 6.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
1.90	7.85
2.00	13.85
3.50	19.65
11.80	27.15
15.50	24.15
17.60	19.35
20.10	18.65
20.20	24.15

TIME . . 7.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
2.00	7.85
2.40	13.95
4.00	19.65
11.50	27.55
16.10	23.55
18.20	18.75
20.20	22.95
20.30	28.65

TABLE A-1. (Continued)

TIME . . 8.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
.90	6.65
2.10	12.85
3.70	18.85
11.20	27.95
15.30	25.15
16.90	23.05
19.70	18.45
21.10	26.15

TIME . . 9.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
.30	6.65
2.10	12.85
3.60	18.85
11.00	28.15
15.10	25.65
16.90	23.25
20.50	20.25
21.00	28.85

TIME . . 10.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
.80	6.65
2.00	12.85
3.50	18.85
10.70	28.45
14.80	26.65
17.10	23.45
20.70	23.05
21.00	31.65

TIME . . 12.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
.80	6.65
1.90	12.85
3.30	18.95
10.40	28.65
15.00	27.95
17.80	23.15
21.00	28.15
20.90	36.85

TIME . . 8.00
RUN . . . 11

HOR.	DEPTH
26.50	42.50
25.90	36.00
24.50	29.70
22.40	23.80
19.50	18.10
16.30	12.80
11.90	7.90
7.10	3.10
0.00	0.00

TIME . . 9.00
RUN . . . 11

HOR.	DEPTH
25.90	42.90
25.40	36.30
24.10	30.00
22.10	24.00
19.30	18.40
16.00	13.00
11.70	8.10
7.00	3.20
0.00	0.00

TIME . . 10.00
RUN . . . 11

HOR.	DEPTH
25.40	43.20
24.80	36.60
23.80	30.40
21.80	24.50
19.00	18.60
15.70	13.30
11.50	8.40
6.90	3.30
0.00	0.00

TIME . . 11.00
RUN . . . 11

HOR.	DEPTH
25.00	43.50
24.40	37.00
23.40	30.70
21.50	24.70
18.70	19.00
15.50	13.50
11.10	8.60
6.80	3.30
0.00	0.00

TIME . . 8.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
2.10	7.85
2.80	13.95
4.50	19.65
11.50	26.65
16.80	22.85
19.60	21.15
20.20	26.85
20.50	32.65

TIME . . 9.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
2.20	7.85
3.20	14.05
5.00	19.55
12.10	26.75
18.20	23.45
20.00	25.95
20.50	30.35
20.50	36.45

TIME . . 10.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
2.30	7.85
3.60	14.15
5.50	19.55
12.90	25.75
19.10	26.25
20.00	28.65
20.40	34.15
20.50	40.55

TIME . . 12.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
2.60	7.95
4.30	14.25
6.50	19.45
15.10	25.45
19.00	31.35
20.00	35.65
20.30	40.95
20.50	46.95

TABLE A-1. (Continued)

TIME . . 14.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
1.00	6.65
2.30	12.85
3.50	19.95
9.60	29.15
14.50	28.25
19.70	24.75
21.00	33.35
20.90	41.85

TIME . . 16.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
1.30	6.65
2.70	12.95
4.10	19.05
11.00	28.15
15.20	27.55
20.30	29.55
20.90	38.15
21.10	46.35

TIME . . 18.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
1.50	6.75
3.20	12.85
5.00	18.95
12.60	27.65
16.50	27.05
20.30	33.95
20.70	42.05
21.00	49.45

TIME . . 20.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
1.80	6.65
3.90	12.65
6.00	18.75
13.50	28.15
18.00	28.65
20.10	37.05
20.50	44.35
20.70	51.15

TIME . . 12.00
RUN . . . 11

HOR.	DEPTH
24.50	44.00
24.00	37.20
23.00	31.00
21.10	25.00
18.40	19.30
15.30	13.80
11.00	8.70
6.60	3.40
0.00	0.00

TIME . . 13.00
RUN . . . 11

HOR.	DEPTH
24.00	44.20
23.60	37.60
22.50	31.50
20.60	25.30
18.10	19.50
15.00	14.00
10.80	8.90
6.40	3.50
0.00	0.00

TIME . . 14.00
RUN . . . 11

HOR.	DEPTH
23.60	44.60
23.10	38.00
22.10	31.70
20.30	25.60
17.70	19.80
14.80	14.10
10.70	9.00
6.20	3.60
0.00	0.00

TIME . . 15.00
RUN . . . 11

HOR.	DEPTH
23.30	45.00
22.80	38.20
21.70	32.00
20.00	25.90
17.50	20.00
14.50	14.40
10.50	9.20
6.10	3.80
0.00	0.00

TIME . . 14.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
2.80	7.95
5.10	14.45
7.50	19.35
16.00	27.65
18.20	33.95
19.70	38.85
20.10	44.85
20.50	51.15

TIME . . 16.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
3.00	7.95
5.90	14.55
8.50	19.25
15.20	29.25
17.20	35.35
19.00	40.65
19.80	46.55
20.00	52.85

TIME . . 18.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
2.80	7.95
5.50	14.55
8.20	19.45
14.40	29.85
16.40	35.85
18.40	41.45
19.20	47.25
19.50	53.55

TIME . . 20.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
2.60	8.05
5.00	14.45
7.90	19.55
14.00	30.15
15.50	36.15
17.30	41.85
18.50	47.65
18.90	53.95

TABLE A-1. (Continued)

TIME . . 30.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
2.10	6.45
4.50	12.65
6.60	18.75
12.90	29.65
15.80	35.05
17.70	40.95
17.60	47.65
18.40	53.55

TIME . . 40.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
1.90	6.55
3.90	12.85
5.70	18.95
10.80	30.45
12.70	36.15
14.50	42.25
14.50	48.65
15.20	54.85

TIME . . 50.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
1.50	6.65
3.20	12.95
4.80	19.15
8.60	31.05
10.50	36.95
11.80	43.15
11.40	49.45
11.80	55.75

TIME . . 60.00
RUN . . . 6

HOR.	DEPTH
0.00	0.00
1.10	6.75
2.50	13.15
3.90	19.35
6.90	31.35
8.30	37.45
9.00	43.75
8.50	50.05
9.20	56.55

TIME . . 16.00
RUN . . . 11

HOR.	DEPTH
22.90	45.20
22.40	38.50
21.30	32.30
19.60	26.20
17.30	20.30
14.00	14.50
10.30	9.40
5.90	4.00
0.00	0.00

TIME . . 17.00
RUN . . . 11

HOR.	DEPTH
22.50	45.50
22.00	38.80
20.90	32.50
19.20	26.50
16.90	20.50
13.70	14.70
10.00	9.50
5.80	4.10
0.00	0.00

TIME . . 18.00
RUN . . . 11

HOR.	DEPTH
22.00	45.90
21.60	39.00
20.50	32.80
18.90	26.70
16.60	20.70
13.50	15.00
9.80	9.80
5.80	4.10
0.00	0.00

TIME . . 19.00
RUN . . . 11

HOR.	DEPTH
21.60	46.10
21.20	39.40
20.10	33.10
18.40	27.00
16.30	21.00
13.30	15.10
9.50	9.80
5.70	4.20
0.00	0.00

TIME . . 30.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
2.00	8.15
3.70	14.35
5.80	20.25
10.00	31.75
11.00	37.85
14.00	43.65
14.90	49.15
15.30	55.35

TIME . . 40.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
1.70	8.15
3.10	14.35
4.20	20.65
7.50	32.35
9.00	38.25
9.50	44.55
10.80	50.25
11.00	56.75

TIME . . 50.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
1.30	8.25
2.50	14.45
3.40	20.75
5.20	32.85
6.00	38.75
6.80	45.05
7.50	50.85
7.60	57.65

TIME . . 60.00
RUN . . . 15

HOR.	DEPTH
0.00	0.00
1.00	8.25
1.90	14.55
2.50	20.85
3.60	33.05
4.00	39.15
3.90	45.35
4.70	51.35
4.50	58.25

TABLE A-1. (Continued)

TIME . .	70.00	TIME . .	20.00	TIME . .	70.00
RUN . . .	6	RUN . . .	11	RUN . . .	15
HOR.	DEPTH	HOR.	DEPTH	HOR.	DEPTH
0.00	0.00	21.30	46.40	0.00	0.00
.80	6.85	20.80	39.50	.70	8.35
2.00	13.25	19.60	33.40	1.20	14.65
3.10	19.55	18.00	27.20	1.70	20.95
5.10	31.75	16.00	21.20	2.40	33.15
6.40	37.75	13.00	15.30	2.50	39.25
6.50	44.25	9.40	10.00	2.00	45.55
6.20	50.35	5.60	4.20	2.40	51.55
6.50	56.95	0.00	0.00	2.00	58.35
TIME . .	80.00	TIME . .	30.00	TIME . .	80.00
RUN . . .	6	RUN . . .	11	RUN . . .	15
HOR.	DEPTH	HOR.	DEPTH	HOR.	DEPTH
0.00	0.00	17.30	48.40	0.00	0.00
.50	6.95	17.00	41.80	.30	8.35
1.40	13.25	16.30	35.30	.60	14.75
2.30	19.65	15.00	29.00	.80	21.05
3.60	32.05	12.90	22.90	1.20	33.25
4.40	38.15	10.50	16.70	1.60	39.45
4.50	44.35	7.50	11.00	.90	45.55
4.00	50.55	4.80	4.80	.80	51.55
4.50	57.35	0.00	0.00	.50	58.35
TIME . .	90.00	TIME . .	40.00	TIME . .	90.00
RUN . . .	6	RUN . . .	11	RUN . . .	15
HOR.	DEPTH	HOR.	DEPTH	HOR.	DEPTH
0.00	0.00	13.50	49.80	0.00	0.00
.30	7.05	13.20	43.20	0.00	8.35
.90	13.35	12.50	36.50	0.00	14.85
1.60	19.75	11.60	30.20	0.00	21.05
2.60	32.15	9.80	23.80	0.00	33.25
2.60	38.25	8.80	17.40	0.00	39.55
2.60	44.55	5.70	11.60	0.00	45.55
2.10	50.65	3.90	5.20	0.00	51.55
2.60	57.35	0.00	0.00	.30	58.35
		TIME . .	50.00		
		RUN . . .	11		
		HOR.	DEPTH		
		9.70	50.70		
		9.60	44.00		
		9.00	37.50		
		8.40	31.00		
		7.50	24.60		
		7.00	18.00		
		4.61	12.00		
		3.10	5.50		
		0.00	0.00		

TABLE A-1. (Continued)

TIME . .	60.00
RUN . . .	11
HOR.	DEPTH
6.50	51.30
6.50	44.60
6.30	37.90
5.90	31.40
5.40	25.00
4.80	18.50
3.60	12.20
2.40	5.70
0.00	0.00
TIME . .	70.00
RUN . . .	11
HOR.	DEPTH
4.10	51.50
4.00	44.90
4.00	38.20
3.70	31.70
3.80	25.10
3.30	18.80
2.80	12.40
1.90	5.90
0.00	0.00
TIME . .	80.00
RUN . . .	11
HOR.	DEPTH
1.90	51.60
2.00	45.00
2.20	38.20
2.00	31.90
2.50	25.30
2.10	18.90
2.20	12.50
1.30	6.00
0.00	0.00
TIME . .	90.00
RUN . . .	11
HOR.	DEPTH
1.00	51.60
1.30	45.00
1.50	38.30
1.40	31.90
1.60	25.40
1.30	18.90
1.50	12.50
1.00	6.00
0.00	0.00

TABLE A-2. CEL 60 FOOT EXPERIMENT: MEASURED FIXED END TENSION FOR RUN 6

CEL 60 FT CABLE EXPERIMENT TENSION DATA

RUN 6-ANCHOR LAST--60 FT CABLE TENSION

TIME SECONDS	HORIZ. POUNDS	UNUSED POUNDS	VERTICAL POUNDS	TENSION POUNDS	PHI DEGREES	THETA DEGREES	RADIAL POUNDS
0.00	.01322	.00142	.05628	.05783	76.707	6.151	.01330
.99	.01307	.00142	.05671	.05822	76.944	6.213	.01315
1.99	.01128	.00167	.04697	.04833	76.359	8.419	.01140
3.00	.01155	.00118	.05048	.05180	77.043	5.848	.01161
3.99	.01127	.00165	.05135	.05260	77.489	8.305	.01139
4.99	.01127	.00149	.05052	.05179	77.320	7.508	.01137
6.00	.01141	.00120	.05337	.05459	77.872	5.995	.01147
6.99	.01141	.00127	.05597	.05714	78.411	6.334	.01148
8.00	.01116	.00125	.05423	.05538	78.296	6.378	.01123
9.00	.01170	.00124	.05867	.05984	78.660	6.054	.01177
9.99	.01155	.00124	.05884	.05998	78.830	6.115	.01162
11.00	.01175	.00114	.05912	.06029	78.711	5.553	.01180
11.98	.01185	.00126	.06109	.06224	78.964	6.076	.01191
12.99	.01175	.00127	.06232	.06343	79.262	6.151	.01182
14.00	.01219	.00129	.06363	.06480	79.096	6.030	.01226
14.98	.01351	.00128	.07403	.07527	79.616	5.410	.01357
15.99	.01371	.00172	.07525	.07650	79.592	7.140	.01382
17.00	.01590	.00141	.08302	.08454	79.116	5.059	.01596
17.99	.01967	.00129	.10126	.10316	78.986	3.742	.01971
18.99	.02434	.00170	.11953	.12199	78.461	3.988	.02440
20.00	.03081	.00216	.14965	.15280	78.338	4.015	.03089
20.99	.03869	.00290	.17415	.17842	77.440	4.282	.03880
22.00	.04397	.00290	.17699	.18240	76.020	3.778	.04406
23.00	.04804	.00359	.19316	.19907	75.996	4.277	.04817
23.99	.05633	.00472	.19453	.20257	73.797	4.792	.05652
25.00	.05973	.00583	.19518	.20420	72.909	5.576	.06001
25.98	.06451	.00565	.19672	.20711	71.780	5.003	.06476
26.99	.07156	.00601	.19742	.21008	70.012	4.803	.07181
28.00	.07685	.00668	.19659	.21118	68.575	4.967	.07714
28.98	.07954	.00785	.19775	.21329	67.991	5.636	.07993
29.61	.07929	.00831	.19766	.21313	68.033	5.985	.07973
30.61	.07857	.00860	.19817	.21335	68.256	6.246	.07904
31.61	.07748	.00827	.19941	.21409	68.655	6.093	.07792
32.59	.07666	.00846	.20048	.21480	68.958	6.294	.07712
33.61	.07579	.00869	.20074	.21474	69.193	6.541	.07628
34.61	.07488	.00781	.20125	.21487	69.490	5.951	.07529
35.60	.07382	.00841	.20141	.21468	69.751	6.497	.07430
36.58	.07298	.00805	.20275	.21563	70.092	6.292	.07342
37.59	.07090	.00866	.20290	.21511	70.606	6.967	.07143
38.58	.07044	.00787	.20432	.21626	70.869	6.374	.07087
39.58	.06877	.00763	.20454	.21592	71.310	6.332	.06919
40.60	.06770	.00797	.20578	.21678	71.671	6.714	.06817
41.59	.06650	.00861	.20596	.21660	71.966	7.375	.06706
42.58	.06494	.00872	.20644	.21659	72.391	7.648	.06552
43.61	.06396	.00849	.20767	.21746	72.741	7.564	.06452
44.61	.06296	.00856	.20726	.21678	72.957	7.746	.06354
45.63	.06159	.00832	.20812	.21720	73.373	7.696	.06215

TABLE A-2. (Continued)

46.61	.06049	.00778	.20853	.21727	73.698	7.326	.06099
47.62	.05948	.00852	.20841	.21690	73.917	8.153	.06009
48.63	.05883	.00866	.20987	.21813	74.180	8.369	.05947
49.63	.05719	.00826	.21008	.21788	74.620	8.217	.05779
50.61	.05635	.00736	.21004	.21759	74.860	7.437	.05683
51.63	.05479	.00734	.21121	.21832	75.333	7.631	.05528
52.62	.05381	.00771	.21107	.21796	75.557	8.157	.05436
53.61	.05260	.00783	.21192	.21850	75.912	8.462	.05318
54.61	.05180	.00765	.21176	.21813	76.110	8.398	.05236
55.61	.05050	.00763	.21248	.21853	76.485	8.587	.05107
56.62	.05022	.00740	.21237	.21836	76.557	8.380	.05076
57.60	.04845	.00766	.21262	.21820	77.010	8.982	.04905
58.63	.04801	.00760	.21309	.21856	77.151	8.992	.04860
59.63	.04670	.00813	.21368	.21888	77.492	9.876	.04741
60.60	.04506	.00715	.21334	.21816	77.928	9.017	.04563
61.61	.04435	.00771	.21468	.21935	78.159	9.859	.04501
62.61	.04331	.00736	.21372	.21818	78.384	9.645	.04393
63.60	.04268	.00761	.21517	.21950	78.608	10.109	.04336
64.60	.04119	.00684	.21522	.21924	79.020	9.432	.04176
65.62	.04056	.00693	.21572	.21961	79.200	9.697	.04115
66.60	.03929	.00694	.21562	.21928	79.516	10.024	.03990
67.58	.03811	.00660	.21577	.21921	79.838	9.827	.03868
68.60	.03754	.00700	.21668	.22002	80.006	10.569	.03818
69.60	.03668	.00620	.21678	.21995	80.262	9.601	.03720
70.58	.03546	.00638	.21695	.21992	80.570	10.193	.03603
71.58	.03474	.00656	.21718	.22004	80.755	10.700	.03535
72.60	.03351	.00643	.21762	.22028	81.088	10.857	.03412
73.60	.03247	.00603	.21748	.21997	81.364	10.527	.03303
74.62	.03209	.00634	.21795	.22039	81.464	11.169	.03271
75.62	.03068	.00562	.21799	.22021	81.856	10.387	.03119
76.62	.03057	.00587	.21828	.22049	81.885	10.880	.03112
77.62	.02927	.00554	.21872	.22074	82.245	10.710	.02979
78.63	.02895	.00572	.21901	.22099	82.327	11.173	.02951
79.63	.02741	.00512	.21856	.22033	82.729	10.577	.02789
80.64	.02669	.00520	.21893	.22061	82.921	11.033	.02719
81.62	.02612	.00552	.21915	.22077	83.054	11.935	.02670
82.62	.02511	.00490	.21886	.22035	83.332	11.037	.02559
83.62	.02438	.00483	.21910	.22050	83.528	11.199	.02485
84.62	.02410	.00513	.21890	.22028	83.579	12.013	.02463
85.62	.02300	.00474	.21955	.22081	83.894	11.638	.02349
86.62	.02185	.00434	.21915	.22028	84.195	11.233	.02228
87.62	.02174	.00475	.21945	.22058	84.210	12.330	.02225
88.62	.02056	.00451	.21960	.22061	84.525	12.377	.02105
89.62	.01978	.00449	.21985	.22078	84.729	12.792	.02028
90.62	.01953	.00479	.21947	.22039	84.765	13.782	.02011
91.62	.01887	.00446	.21969	.22055	84.956	13.307	.01939

TABLE A-3. CEL 60 FOOT EXPERIMENT: MEASURED FIXED END TENSION FOR RUN 11

CEL 60 FT CABLE EXPERIMENT TENSION DATA
RUN 11-RELAXATION--60 FT CABLE TENSION

TIME SECONDS	HORIZ. POUNDS	UNUSED POUNDS	VERTICAL POUNDS	TENSION POUNDS	PHI DEGREES	THETA DEGREES	RADIAL POUNDS
0.00	-.00054	.00088	-.00079	.00130	-37.695	121.573	.00103
.99	-.00056	.00191	-.00064	.00209	-17.714	106.250	.00199
1.99	-.00083	.00261	-.00360	.00452	-52.756	107.642	.00273
3.00	.01151	-.10405	.04811	.11521	24.682	-83.690	.10468
3.99	.02214	-.17385	.10213	.20284	30.231	-82.743	.17526
4.99	.01992	-.18261	.12471	.22202	34.172	-83.773	.18369
6.00	.01907	-.17502	.13496	.22183	37.473	-83.781	.17606
6.99	.02075	-.17432	.14761	.22937	40.059	-83.212	.17555
8.00	.01854	-.17138	.15728	.23335	42.377	-83.826	.17238
8.98	.01944	-.16724	.16257	.23404	43.998	-83.369	.16836
9.99	.02090	-.16402	.16610	.23437	45.131	-82.737	.16535
11.00	.01867	-.15856	.17229	.23489	47.180	-83.284	.15965
11.98	.01972	-.15594	.17524	.23540	48.110	-82.791	.15718
12.99	.01743	-.15246	.17915	.23589	49.416	-83.477	.15346
14.00	.01790	-.14829	.18339	.23652	50.839	-83.119	.14937
14.98	.01905	-.14565	.18618	.23715	51.726	-82.550	.14689
15.99	.01607	-.14241	.19029	.23822	53.016	-83.564	.14331
17.00	.01774	-.13846	.19361	.23869	54.208	-82.697	.13960
17.99	.01775	-.13489	.19505	.23781	55.103	-82.503	.13605
18.99	.01780	-.13140	.19880	.23897	56.297	-82.284	.13260
19.53	.01708	-.12943	.20044	.23921	56.923	-82.482	.13055
20.52	.01700	-.12557	.20286	.23918	58.008	-82.291	.12672
21.50	.01552	-.13587	.20532	.24670	56.334	-83.483	.13676
22.50	.01472	-.11815	.20865	.24023	60.289	-82.896	.11906
23.50	.01500	-.11538	.21236	.24214	61.282	-82.592	.11635
24.50	.01605	-.11136	.21394	.24172	62.260	-81.800	.11251
25.49	.01550	-.10688	.21396	.23967	63.217	-81.751	.10800
26.49	.01546	-.10463	.21894	.24315	64.215	-81.593	.10577
27.49	.01434	-.10113	.22176	.24415	65.269	-81.927	.10214
28.51	.01415	-.09787	.22417	.24501	66.198	-81.775	.09888
29.49	.01368	-.09395	.22486	.24408	67.110	-81.718	.09494
30.48	.01289	-.09075	.22722	.24501	68.031	-81.915	.09166
31.49	.01299	-.08746	.22905	.24552	68.892	-81.554	.08842
32.49	.01214	-.08466	.23072	.24606	69.660	-81.839	.08553
33.48	.01254	-.08107	.23265	.24669	70.578	-81.207	.08203
34.49	.01320	-.07867	.23371	.24694	71.155	-80.477	.07976
35.49	.01119	-.07551	.23609	.24812	72.084	-81.571	.07633
36.47	.01055	-.07226	.23775	.24871	72.925	-81.692	.07302
37.46	.01051	-.06869	.23796	.24790	73.720	-81.302	.06949
38.46	.01114	-.06546	.23972	.24874	74.517	-80.340	.06640
39.49	.01108	-.06271	.24142	.24968	75.223	-79.984	.06368
40.47	.01206	-.06098	.24173	.24960	75.580	-78.0[illegible]	.06216
41.47	.00997	-.05710	.24373	.25053	76.623	-80.095	.05796
42.47	.01099	-.05413	.24379	.24997	77.234	-78.527	.05523
43.49	.01052	-.05183	.24595	.25157	77.864	-78.532	.05289
44.49	.01017	-.04862	.24702	.25196	78.629	-78.185	.04968
45.49	.00971	-.04603	.24731	.25175	79.230	-78.088	.04704

TABLE A-3. (Continued)

46.47	.00968	-.04348	.24880	.25276	79.839	-77.196	.04459
47.52	.00895	-.04024	.25049	.25386	80.654	-77.459	.04123
48.50	.00918	-.03759	.25202	.25497	81.271	-76.283	.03870
49.50	.00862	-.03476	.25365	.25617	81.964	-76.064	.03581
50.51	.00725	-.03159	.25417	.25623	82.733	-77.071	.03241
51.50	.00712	-.02870	.25411	.25582	83.362	-76.068	.02957
52.49	.00768	-.02610	.25449	.25594	83.898	-73.593	.02721
53.47	.00645	-.02400	.25443	.25564	84.421	-74.958	.02485
54.49	.00566	-.02126	.25514	.25608	85.071	-75.104	.02200
55.48	.00665	-.01881	.25738	.25815	85.568	-70.526	.01995
56.48	.00527	-.01587	.25666	.25721	86.271	-71.629	.01673
57.49	.00447	-.01372	.25777	.25817	86.796	-71.968	.01443
58.50	.00498	-.01102	.25830	.25858	87.320	-65.672	.01209
59.48	.00471	-.00915	.26029	.26049	87.736	-62.769	.01029
60.47	.00434	-.00694	.26038	.26051	88.199	-57.979	.00819
61.50	.00419	-.00462	.26045	.26052	88.628	-47.779	.00624
62.48	.00341	-.00289	.26004	.26008	89.016	-40.292	.00447
63.47	.00398	-.00008	.26084	.26087	89.126	-1.104	.00398
64.47	.00466	.00165	.26146	.26151	88.916	19.508	.00495
65.48	.00365	.00375	.26232	.26238	88.858	45.741	.00523
66.46	.00391	.00587	.26247	.26256	88.460	56.356	.00705
67.45	.00368	.00795	.26281	.26296	88.092	65.172	.00876
68.45	.00292	.00921	.26335	.26353	87.900	72.429	.00966
69.46	.00217	.01167	.26391	.26418	87.425	79.447	.01187
70.46	.00303	.01319	.26410	.26444	87.065	77.054	.01354
71.46	.00287	.01510	.26457	.26501	86.674	79.234	.01537
72.46	.00189	.01678	.26446	.26499	86.347	83.573	.01689
73.48	.00101	.01836	.26464	.26527	86.026	86.839	.01838
74.48	.00237	.02010	.26432	.26509	85.622	83.281	.02024
75.48	.00174	.02190	.26553	.26644	85.271	85.451	.02197
76.49	.00075	.02311	.26528	.26629	85.019	88.136	.02312
77.50	.00206	.02444	.26540	.26653	84.721	85.178	.02452
78.49	.00034	.02584	.26703	.26828	84.472	89.238	.02585
79.49	.00073	.02734	.26515	.26656	84.111	88.470	.02735
80.51	.00073	.02910	.26608	.26767	83.756	88.557	.02911
81.49	.00104	.03020	.26579	.26750	83.515	88.034	.03021
82.47	.00003	.03162	.26664	.26851	83.238	89.954	.03162
83.47	.00067	.03241	.26616	.26812	83.056	88.820	.03242
84.48	-.00055	.03346	.26593	.26803	82.828	90.941	.03346
85.47	.00041	.03478	.26625	.26851	82.558	89.322	.03478
86.47	-.00037	.03586	.26623	.26863	82.328	90.592	.03586
87.48	-.00042	.03655	.26611	.26861	82.179	90.651	.03655
88.48	-.00086	.03751	.26632	.26895	81.980	91.320	.03752
89.47	-.00055	.03856	.26658	.26935	81.769	90.820	.03856
90.47	-.00102	.03918	.26720	.27006	81.655	91.494	.03919
91.47	-.00079	.03996	.26677	.26975	81.479	91.136	.03997
92.47	-.00094	.04063	.26681	.26988	81.339	91.319	.04064
93.46	-.00130	.04124	.26661	.26978	81.203	91.802	.04126
94.47	-.00139	.04186	.26724	.27050	81.093	91.899	.04188
95.47	-.00158	.04255	.26679	.27017	80.933	92.133	.04258
96.45	-.00158	.04268	.26721	.27060	80.918	92.121	.04271
97.44	-.00167	.04301	.26723	.27067	80.851	92.251	.04304

TABLE A-4. CEL 60 FOOT EXPERIMENT: MEASURED FIXED END TENSION FOR RUN 15

CEL 60 FT CABLE EXPERIMENT TENSION DATA
RUN 15-ANCHOR LAST-60 FT CABLE TENSION

TIME SECONDS	HORIZ. POUNDS	UNUSED POUNDS	VERTICAL POUNDS	TENSION POUNDS	PHI DEGREES	THETA DEGREES	RADIAL POUNDS
0.00	.00140	-.01017	.05902	.05990	80.137	-82.161	.01026
1.01	.00120	-.00867	.04347	.04434	78.615	-82.106	.00875
2.02	.00101	-.00867	.05185	.05258	80.441	-83.389	.00873
3.00	.00101	-.00857	.05199	.05270	80.576	-83.289	.00863
4.01	.00120	-.00857	.05169	.05240	80.500	-82.000	.00865
4.99	.00125	-.00850	.05401	.05469	80.963	-81.604	.00859
6.00	.00047	-.00872	.05498	.05567	80.974	-86.942	.00873
7.01	.00115	-.00859	.05594	.05660	81.191	-82.354	.00867
8.00	-.00025	-.01127	.07086	.07175	80.958	-91.256	.01128
9.00	-.00035	-.01476	.09038	.09157	80.719	-91.372	.01477
9.99	-.00045	-.01955	.11014	.11187	79.934	-91.316	.01955
11.00	.00116	-.02936	.15039	.15323	78.944	-87.738	.02939
12.01	.00218	-.04101	.19739	.20161	78.246	-86.963	.04107
12.99	.00667	-.06206	.26098	.26834	76.549	-83.863	.06242
14.00	.00420	-.08274	.31033	.32119	75.053	-87.094	.08284
15.01	.00983	-.09709	.32585	.34015	73.328	-84.218	.09759
15.99	.01656	-.11740	.33386	.35429	70.448	-81.972	.11856
17.00	.01955	-.13015	.33795	.36267	68.722	-81.457	.13161
18.01	.02265	-.14451	.33237	.36314	66.246	-81.093	.14628
18.99	.02438	-.15046	.33134	.36472	65.297	-80.797	.15242
20.00	.02507	-.15026	.33484	.36787	65.536	-80.529	.15234
21.01	.02484	-.14628	.33464	.36606	66.088	-80.362	.14838
22.00	.02501	-.14381	.33494	.36537	66.453	-80.133	.14597
23.00	.02205	-.13982	.34158	.36975	67.491	-81.038	.14155
23.99	.02422	-.13753	.34270	.37006	67.830	-80.012	.13964
25.00	.02042	-.13398	.34109	.36703	68.330	-81.336	.13553
26.01	.02129	-.12923	.34545	.36944	69.237	-80.645	.13097
27.01	.02202	-.12581	.34363	.36660	69.611	-80.070	.12772
28.00	.02117	-.12313	.34599	.36786	70.145	-80.242	.12494
29.01	.01983	-.11906	.35090	.37108	71.019	-80.545	.12070
29.99	.02001	-.11626	.35121	.37049	71.433	-80.235	.11797
31.00	.01761	-.11303	.35050	.36869	71.925	-81.143	.11439
32.01	.01967	-.10943	.35399	.37104	72.563	-79.809	.11119
32.99	.01692	-.10668	.35222	.36841	72.951	-80.988	.10802
34.00	.01820	-.10461	.35455	.37011	73.327	-80.130	.10619
34.99	.01768	-.10234	.35781	.37258	73.815	-80.197	.10385
36.00	.01659	-.09809	.35681	.37042	74.422	-80.402	.09948
37.00	.01568	-.09562	.35808	.37096	74.858	-80.687	.09690
37.99	.01508	-.09274	.35972	.37179	75.362	-80.763	.09396
39.00	.01574	-.09040	.35954	.37106	75.684	-80.124	.09175
39.56	.01487	-.08824	.36093	.37186	76.075	-80.433	.08949
40.54	.01361	-.08616	.36169	.37206	76.441	-81.020	.08722
41.54	.01458	-.08318	.36189	.37161	76.865	-80.057	.08445
42.54	.01279	-.08085	.36313	.37224	77.297	-81.008	.08185
43.53	.01437	-.07884	.36337	.37210	77.563	-79.672	.08014
44.52	.01213	-.07668	.36371	.37191	77.951	-81.007	.07763
45.54	.01373	-.07399	.36451	.37220	78.335	-79.489	.07526

TABLE A-4. (Continued)

46.54	.01346	-.07146	.36528	.37245	78.741	-79.363	.07272
47.54	.01296	-.06868	.36608	.37270	79.191	-79.318	.06990
48.54	.01218	-.06679	.36650	.37273	79.505	-79.664	.06789
49.56	.01259	-.06456	.36662	.37248	79.829	-78.966	.06577
50.56	.01029	-.06137	.36700	.37223	80.377	-80.482	.06222
51.56	.01104	-.05907	.36817	.37304	80.731	-79.412	.06009
52.56	.01073	-.05617	.36923	.37363	81.195	-79.181	.05719
53.56	.01050	-.05422	.36930	.37340	81.495	-79.040	.05523
54.58	.01053	-.05168	.36962	.37336	81.879	-78.489	.05274
55.56	.00976	-.04932	.37182	.37520	82.300	-78.801	.05027
56.58	.00934	-.04717	.37027	.37338	82.601	-78.801	.04808
57.58	.00745	-.04500	.37043	.37323	82.980	-80.601	.04561
58.56	.00795	-.04301	.37301	.37556	83.313	-79.531	.04373
59.55	.00795	-.04115	.37304	.37539	83.590	-79.061	.04191
60.56	.00811	-.03898	.37169	.37382	83.886	-78.241	.03982
61.57	.00800	-.03774	.37214	.37414	84.081	-78.026	.03858
62.56	.00612	-.03536	.37285	.37458	84.502	-80.181	.03589
63.56	.00725	-.03362	.37328	.37486	84.736	-77.838	.03439
64.56	.00667	-.03147	.37340	.37478	85.076	-78.025	.03217
65.56	.00682	-.02991	.37341	.37467	85.303	-77.161	.03068
66.57	.00719	-.02877	.37366	.37483	85.463	-75.959	.02965
67.56	.00637	-.02672	.37394	.37495	85.798	-76.582	.02747
68.55	.00627	-.02533	.37412	.37503	86.011	-76.098	.02609
69.57	.00617	-.02357	.37403	.37482	86.272	-75.324	.02437
70.56	.00476	-.02170	.37398	.37464	86.600	-77.620	.02222
71.55	.00543	-.02070	.37419	.37480	86.726	-75.307	.02140
72.56	.00526	-.01978	.37437	.37492	86.871	-75.105	.02046
73.53	.00477	-.01824	.37432	.37480	87.117	-75.351	.01885
74.53	.00457	-.01680	.37438	.37478	87.338	-74.794	.01741
75.53	.00431	-.01557	.37430	.37465	87.529	-74.527	.01615
76.55	.00381	-.01434	.37467	.37496	87.732	-75.127	.01484
77.55	.00388	-.01346	.37454	.37480	87.858	-73.909	.01401
78.55	.00404	-.01309	.37480	.37505	87.906	-72.850	.01370
79.57	.00384	-.01150	.37472	.37491	88.147	-71.518	.01212
80.59	.00309	-.01069	.37470	.37486	88.299	-73.906	.01113
81.57	.00335	-.01002	.37413	.37428	88.383	-71.512	.01056
82.57	.00293	-.00946	.37488	.37501	88.487	-72.807	.00990
83.58	.00266	-.00843	.37452	.37463	88.647	-72.474	.00884
84.59	.00263	-.00787	.37468	.37477	88.732	-71.503	.00829
85.59	.00279	-.00749	.37535	.37543	88.779	-69.592	.00800
86.59	.00246	-.00704	.37458	.37465	88.859	-70.749	.00746
87.58	.00209	-.00643	.37464	.37470	88.966	-72.029	.00677
88.57	.00209	-.00623	.37492	.37498	88.996	-71.417	.00657
89.56	.00211	-.00581	.37520	.37525	89.056	-70.082	.00618
90.57	.00212	-.00540	.37466	.37470	89.113	-68.589	.00580
91.57	.00212	-.00540	.37466	.37470	89.113	-68.589	.00580
92.57	.00207	-.00530	.37467	.37471	89.130	-68.645	.00569
93.57	.00213	-.00514	.37466	.37470	89.149	-67.544	.00556
94.57	.00178	-.00510	.37471	.37475	89.174	-70.715	.00540
95.57	.00183	-.00510	.37456	.37460	89.171	-70.225	.00542
96.57	.00198	-.00525	.37468	.37472	89.142	-69.379	.00561
97.57	.00197	-.00536	.37440	.37445	89.127	-69.779	.00571

APPENDIX B

STATIC COMPARISONS

APPENDIX B

STATIC COMPARISONS

The experimental data were evaluated by comparing the static configuration measured at the start of each experimental run and the nearly static configuraion measured at the end of each run with the equations describing the configuration of a static, elastic cable. These equations were evaluted using measured values for the line elasticity and immersed weight as well as the immersed weight of the anchor and buoyancy of the buoy. The equations are:

$$X = (\alpha/\omega + s/AE)\cdot H, \tag{B-1}$$

$$Y = (V_1+V_2)\cdot s/AE + (T_2-T_1)/\omega \tag{B-2}$$

$$S = (H^2\alpha + V_2T_2 - V_1T_1)/2\cdot\omega\cdot AE + s, \tag{B-3}$$

$$T_i = \sqrt{H^2 + V_i^{\,2}}\text{, and} \tag{B-4}$$

$$V_2 = V_1 + \omega s\text{, where} \tag{B-5}$$

X = horizontal span between points 1 and 2,
Y = vertical span between points 1 and 2,
S = stretched line length points 1 and 2,
V_i = vertical force at point i, = 1, 2,
T_i = line tension at point i,
s = unstretched amount of line between 1 and 2,
H = horizontal force acting on line,
ω = immersed weight of line,
AE = elastic constant of line, and
$\alpha = \ln (V_2+T_2) - \ln (V_1+ T_1)\cdot$ (B-6)

In the limit as AE becomes infinite, these equations become the classical catenary equation. The angle of the cable at any point is given by:

$$\phi_i = \tan^{-1} (V_i/H) \tag{B-7}$$

Tables B-1 through B-3 show the comparison of Runs 6, 11, 15 with the static catenaries computed from the above relations for conditions at the start of the run. The boundary conditions are that the two ends of the measured length of line are fixed at the measured positions. The locations of other points may be compared, as well as the force components acting on the fixed end.

At the end of each run, the cable is very nearly in static equilibrium, so that a second comparison can be made. In these cases, two boundary conditions could be imposed:

(a) that the two ends of the cable agree, as at the start of the run, or

(b) that the fixed end agree in position and the free end (buoy or anchor) agree in horizontal displacement and vertical force (buoyancy or weight).

The latter assumption gave, as might be expected, closer agreement with the data, and was adopted. The results are shown on Tables B-4 through B-6.

Finally, Table B-7 summarizes the differences between the measured values and the catenary equations.

TABLE B-1. CEL 60 FOOT EXPERIMENT - RUN 6 AT START

SUBJECT: CEL-60 FT XPT - RUN 6 — 0 SECONDS

COINCIDENCE AT FIXED END AND NODE 9

DATE: APRIL '79

SHEET NO 1 OF 3 SHEETS

LINE NO. j	COL. A V(j)	COL. B	COL. C NODE	COL. D s	COL. E DATA	COL. F X CALC	COL. G Δ	COL. H DATA	COL. I Y CALC	COL. J Δ	COL. K R	COL. L
1	Æ	4.805	FIXED	0	0	0	—	0	0	—	—	
2	W	.0024	1	6.63	1.00	1.084	+.084	6.65	6.625	-.025	.088	
3	H	.009668	2	12.72	2.50	2.409	-.091	12.75	12.626	-.124	.154	
4	V_1	-.06740	3	18.77	4.50	4.328	-.172	18.65	18.397	-.251	.304	
5	X	21.20	4	24.84	—	7.718	—	—	23.393	—	—	
6	Y	-1.25	5	30.82	14.00	13.258	-.742	23.65	23.695	.045	.743	
7	S	0	6	36.85	17.60	16.832	-.768	18.65	18.900	.250	.808	
8	s	54.92	7	42.89	19.30	18.830	-.470	12.55	13.168	.618	.776	
9	$\mathcal{E}_x$		8	48.92	20.50	20.183	-.317	6.35	7.236	.886	.941	
10	$\mathcal{E}_y$		9	54.92	21.20	21.200	—	1.25	1.250	—	—	
11	$\mathcal{E}_s$		ANCHOR	55.15	—	21.234	—	—	1.019	—	—	
12	V_2		MEAN				-.354			+.200	.545	
13	T_2		σ				.324			.414	.351	
14	T_1											
15	ϕ_2					H			V			
16	ϕ_1		FIXED		.01322	.009668	-.004	.05628	.067399	.011		
17	α		ANCHOR									
18												
19												
20												

TABLE B-2. CEL 60 FOOT EXPERIMENT - RUN 11 AT START

SUBJECT: CEL - 60 FT XPT - RUN 11 - 0 SECONDS

COINCIDENCE AT FIXED END AND NODE 1

DATE: APRIL '79

SHEET NO. 2 OF 3 SHEETS

LINE NO. j	COL. A	COL. B	COL. C	COL. D	COL. E	COL. F	COL. G	COL. H	COL. I	COL. J	COL. K	COL. L
	V(j)		NODE	r	DATA	X CALC.	Δ	DATA	Y CALC.	Δ	R	
1	Æ	3.887	BUOY	51.16	—	29.659	—	—	37.084	—	—	
2	W	.0020	1	50.57	29.50	29.500	—	36.50	36.500	—	—	
3	H	.02614	2	44.48	28.40	27.742	-.658	30.60	30.518	-.082	.663	
4	V_1	-.00600	3	38.42	26.10	25.747	-.353	25.20	24.662	-.538	.643	
5	X	29.50	4	32.37	23.50	23.438	-.062	19.90	18.954	-.946	.948	
6	Y	36.50	5	26.32	20.50	20.702	.202	14.50	13.458	-1.042	1.061	
7	S	0	6	20.29	17.10	17.388	.288	9.60	8.336	-1.264	1.296	
8	r	50.57	7	14.21	13.10	13.277	.127	4.90	3.837	-1.063	1.071	
9	ε_x		8	8.16	8.00	8.064	.064	0.80	.645	-0.155	.168	
10	ε_y		FIXED	0	0	0	—	0	0	—	—	
11	ε_s		MEAN				-.056			-.727	.836	
12	V_2		σ				.338			.470	.375	
13	T_2											
14	T_1					H			V			
15	ϕ_2		FIXED		.00054	.02614	.026	-.00079	-.00601	-.005		
16	ϕ_1		BUOY									
17	α											
18												
19												
20												

TABLE B-3. CEL 60 FOOT EXPERIMENT - RUN 15 AT START

SUBJECT: CEL - 60 FT XPT. - RUN 15 - 0 SECONDS

COINCIDENCE AT FIXED END AND NODE 1

DATE: APRIL '79

SHEET NO. 3 OF 3

LINE NO. j	COL. A	COL. B	COL. C	COL. D	COL. E	COL. F	COL. G	COL. H	COL. I	COL. J	COL. K	COL. L
						X			Y			
	V(j)		NODE	a	DATA	CALC	Δ	DATA	CALC	Δ	R	
1	Æ	4.805	FIXED	0	0	0	—	0	0	—	—	
2	W	.0024	9	6.63	.90	1.029	.129	7.75	6.633	-1.117	1.124	
3	H	.009165	8	12.72	2.50	2.288	-.212	13.75	12.649	-1.101	1.121	
4	V_1	-.067398	7	18.77	4.20	4.117	-.083	19.35	18.451	-0.899	0.903	
5	X	20.50	6	24.84	—	7.388	—	—	23.526	—	—	
6	Y	1.25	5	30.82	13.60	12.887	-.713	24.05	23.837	-0.213	0.744	
7	S	0	4	36.85	17.00	16.344	-.656	19.35	18.956	-0.394	0.765	
8	a	54.92	3	42.89	18.70	18.249	-.451	13.35	13.191	-0.159	0.478	
9	$\mathcal{E}_x$		2	48.92	19.80	19.535	-.265	7.45	7.245	-0.205	0.335	
10	$\mathcal{E}_y$		1	54.92	20.50	20.500	—	1.25	1.250	—	—	
11	$\mathcal{E}_s$		ANCHOR	55.15	—	20.533	—	—	1.019	—	—	
12	V_2		MEAN				-0.322			-0.584	0.782	
13	T_2		σ				0.305			0.438	0.300	
14	T_1											
15	ϕ_2					H			V			
16	ϕ_1		FIXED		.00140	.009165	0.008	-.05902	-.067398	0.008		
17	α		ANCHOR									
18												
19												
20												

TABLE B-4. CEL 60 FOOT EXPERIMENT - RUN 6 AT END

SUBJECT: CEL 60 FT XPT - RUN 6 - 90 SECONDS

COINCIDENCE AT ANCHOR WEIGHT, X-DISP OF NODE 9

DATE: 28 MAR '80

SHEET NO. 1 OF 6 SHEETS

LINE NO. j	COL. A	COL. B	COL. C	COL. D	COL. E	COL. F	COL. G	COL. H	COL. I	COL. J	COL. K	COL. L
						X			Y			
	V(j)		NODE	s	DATA	CALC	Δ	DATA	CALC	Δ	r	
1	A	4.805	FIXED	0	0	0	—	0	0	—	—	
2	W	.0024	1	6.63	0.30	0.227	-0.073	7.05	6.947	+0.103	0.126	
3	H	.005974	2	12.72	0.90	0.450	-0.450	13.35	13.309	+0.041	0.452	
4	V_1	-.2405	3	18.77	1.60	0.686	-0.914	19.75	19.610	+0.140	0.925	
5	X	2.615	4	24.84	—	0.941	—	—	25.913	—	—	
6	Y		5	30.82	2.60	1.212	-1.388	32.15	32.103	+0.047	1.389	
7	S		6	36.85	2.60	1.509	-1.091	38.25	38.326	-0.076	1.094	
8	s	55.15	7	42.89	2.60	1.835	-.765	44.55	44.540	+0.010	0.765	
9	$\mathcal{E}_x$		8	48.92	2.10	2.196	+.096	50.65	50.723	-0.073	0.121	
10	$\mathcal{E}_y$		9	54.92	2.60	2.599	-.001	57.35	+56.855	0.495	0.495	
11	$\mathcal{E}_s$		ANCHOR	55.15	—	2.615	—	—	57.089	—	—	
12	V_2						-0.573			0.086	0.671	MEAN
13	T_2	.1084					0.551			0.182	0.454	σ
14	T_1					H			V			
15	ϕ_2		FIXED	0	.020+	.0076	-.0124	.220+	.2405	-.0205	.0240	
16	ϕ_1		ANCHOR	55.15	—	.0076	—	.1081*	.1081	—	—	
17	α							+ = LOAD CELL				
18								* = ANCHOR WGT				
19												
20												

TABLE 3-5. CEL 60 FOOT EXPERIMENT - RUN 11 AT END

CEL 60 FT XPT - RUN 11 - 90 SECONDS — DATE 28 MAR. '80

COINCIDENCE ON BUOY LIFT AND HOR. DISP. AT NODE 1 — SHEET NO. 3 OF 6 SHEETS

LINE NO. j	COL. A	COL. B	COL. C	COL. D	COL. E	COL. F	COL. G	COL. H	COL. I	COL. J	COL. K	COL. L
	V(j)		NODE	s	DATA	X CALC	Δ	DATA	Y CALC	Δ	R	
1	A	3.887	BUOY	51.16	—	1.060	—	—	55.875	—	—	
2	W	.0020	1	50.57	1.00	1.000	0.000	5160	55.222	3.622	3.622	
3	H	.0064475	2	44.48	1.30	0.892	-0.408	45.00	48.502	3.502	3.526	
4	V_1	.30768	3	38.42	1.50	0.782	-0.718	38.30	41.834	3.534	3.606	
5	X		4	32.37	1.40	0.669	-0.731	31.90	35.196	3.296	3.376	
6	Y		5	26.32	1.60	0.553	-1.047	25.40	28.577	3.177	3.345	
7	S		6	20.29	1.30	0.433	-0.867	18.90	21.998	3.098	3.217	
8	s		7	14.21	1.50	0.308	-1.192	12.50	15.384	2.884	3.121	
9	$\mathcal{E}_x$		8	8.16	1.00	0.180	-0.820	6.00	8.821	2.821	2.938	
10	$\mathcal{E}_y$		FIXED	0.00	0.00	0.00	~~0.00~~	0.00		—	—	
11	$\mathcal{E}_s$						- 0.723			3.242	3.344	MEAN
12	V_2	.4100					0.374			0.300	0.242	σ
13	T_2											
14	T_1					H			V			
15	ϕ_2		BUOY		—	.00645	—	.9100*	.4100	—	—	
16	ϕ_1		FIXED		.0359+	.00645	-.0325	.2669+	.3077	.0408	.0522	
17	α											
18												
19	PT. 1 =	FIXED	s = 0	+ = LOAD CELL								
20	PT. 2 =		s = s	* = NET BUOYANCY								
21												

TABLE B-6. CEL 60 FOOT EXPERIMENT - RUN 15 AT END

SUBJECT: CEL 60 FT XPT - RUN 15 - 90 SECONDS

COINCIDENCE ON ANCHOR WEIGHT AND HOR. DISP. AT NODE 9

DATE: 28 MAR '80

SHEET NO. 5 OF 6 SHEETS

LINE NO. j	COL. A	COL. B	COL. C	COL. D	COL. E	COL. F	COL. G	COL. H	COL. I	COL. J	COL. K	COL. L
	V(j)		NODE	s	DATA	X CALC	Δ	DATA	Y CALC	Δ	R	
1	A	4.805	FIXED	0	0	0	—	0	0	—	—	
2	W	.0024	1	6.63	0	0.031	0.031	8.35	7.149	1.201	1.201	
3	H	.0016084	2	12.72	0	0.060	0.060	14.85	13.696	1.154	1.156	
4	V_1	-.38416	3	18.77	0	0.090	0.090	21.05	20.182	0.868	0.873	
5	X		4	24.84	—	0.121	—	—	26.672	—	—	
6	Y		5	30.82	0	0.154	0.154	33.25	33.047	0.203	0.255	
7	S		6	36.85	0	0.188	0.188	39.55	39.457	0.093	0.210	
8	s		7	42.89	0	0.223	0.223	45.55	45.859	-0.309	0.381	
9	$\mathcal{E}_x$		8	48.92	0	0.261	0.261	51.55	52.233	-0.683	0.731	
10	$\mathcal{E}_y$		9	54.92	0.30	0.300	0.00	58.35	58.577	0.227	0.227	
11	$\mathcal{E}_s$		ANCHOR	55.15	—	0.302	—	—	58.799	—	—	
12	V_2	.25180					0.126			0.344	0.629	MEAN
13	T_2	.25181					0.095			0.681	0.416	σ
14	T_1	.38416										
15	ϕ_2	89.634				H			V			
16	ϕ_1	89.760	FIXED		.0060 +	.00161	-.00439	.3777 +	.3842	.00646	.00781	
17	α		ANCHOR		—	.00161	—	.2518 *	.2518	—	—	
18								+ = LOAD CELL				
19								* = ANCHOR WGT.				
20												

TABLE B-7. SUMMARY OF STATIC COMPARISONS

RUN		DISPLACEMENT DIFFERENCE (FEET)					
		X		Y		R	
		MEAN	DEV.	MEAN	DEV.	MEAN	DEV.
6	START	-0.354	0.324	0.200	0.414	0.545	0.351
	END	-0.573	0.551	0.086	0.182	0.671	0.454
11	START	-0.056	0.338	0.727	0.470	0.836	0.375
	END	-0.723	0.374	3.242	0.300	3.344	0.242
15	START	-0.322	0.305	0.584	0.438	0.782	0.300
	END	-0.126	0.095	0.344	0.681	0.629	0.416

RUN	FIXED END	FORCE DIFFERENCE (POUNDS)					
		H		V		T	
		MEAN	DIFF.	MEAN	DIFF.	MEAN	DIFF.
6	START	-	-0.004	-	0.011	-	0.010
	END	-	-0.012	-	-0.021	-	0.024
11	START	-	0.026	-	-0.005	-	0.026
	END	-	-0.033	-	0.041	-	0.052
15	START	-	0.008	-	0.008	-	0.008
	END	-	-0.004	-	0.006	-	0.008

APPENDIX C
SEADYN AND SNAPLOAD PROGRAM INPUT DATA

APPENDIX C
SEADYN AND SNAPLOAD PROGRAM INPUT DATA

Figures C-1, C-2, and C-3 show the input data supplied to the SEADYN program for modeling Runs 6, 11, and 15. The data are input as 80-column card images. The five digits in the left margin number the cards, and the text in the right margin describes the data. The last two lines in each figure provide a card-column index. In brief, card one contains the title of the problem being modeled. Card two is used to select major program options and set the number of nodes. Card three is used to specify the environmental parameters: gravity, density and viscosity. The dimensional units used with the remaining cards must be consistent with the units associated with these parameters. Card four begins a group that describes the node distribution along the cable and specifies any constraints to be imposed on each node. Taking Figure C-1 for Run 6 as an example, this group of node cards ends with card 14. Cards 15 and 16 specify how the nodes are connected. In this simple case having all nodes serially connected by elements having a single material, it is enough to specify only the first and last linkages. SEADYN adds intermediate elements that follow the pattern. Card 17 gives the physical parameters of the single element material; cards 18-23 give points along its tension-strain curve. The anchor parameters are given on card 24. Cards 25-27 control the calculation of the initial status of the cable system. Cards 29-31 control the calculation of the dynamic response of the system. Card 32 stops the computer run.

Figures C-4, C-5, and C-6 present the SNAPLOAD data deck for Runs 6, 11, and 15, respectively. As in the previous figure, the lines represent punched-card images; characters preceding card-column one and after card-columns 80 are not part of the input data. The first and last two lines in each figure indicate card-columns for convenience; they are not part of the input data.

A detailed description of the data structure is given in Reference 7, the SNAPLOAD user's manual. Like the SEADYN deck, the first card in the deck contains the run title and the second card contains the selection of major options. The 'static' card limits the iterations to find the initial equilibrium, and the 'time spec.' card gives the duration and time increment of the dynamic event to be modeled. The 'instability' card forces abrupt events to take a finite time to occur. The 'support' card identifies a node that may not deviate from the upper boundary during the event. The boundary card specifies the location of the water surface and bottom along a vertical axis. The next two cards specify the water motion as a function of depth - none for these runs. The 'nodes' card gives the number of nodes for each cable; for Run 6, 15 nodes on one cable. The 'segments' card gives the number of segments used for each cable. The 'buoy/anchor' card enters the physical properties of the end node. The 'cable material' card gives physical properties of the rubber cord. It is followed by cards showing the distribution of nodes along the cable. Following the 'half-segment lengths' sub-deck is the 'node location' sub-deck, which provides an estimate of the position of each node at the start of the run. These estimates are refined by SNAPLOAD before commencing the dynamic calculations. Finally, there are the 'plot' file control cards and the 'end' of the run card.

```
CEL 60 FOOT EXPERIMENT-SEADYN MODEL-J. DILLON-RUN 5: ANCHOR LAST-SEPT 79          CASE TITLE
     19    1    0    0   18    1    1    0    1    1    1   0.   0.   0             MASTER CONTROL
      2    0    32.1725 1.2817E-5   64.0394   1.6E-4   0.07528     0.       70.  ENVIRONMENT
      1    0      55.15          0.          0.    0    0    1                   ANCHOR NODE
      2    0      54.92          0.          0.    0    0    1                   CABLE NODE 1
      4    1      48.92          0.          0.    0    0    1                   CABLE NODE 2
      6    1      42.89          0.          0.    0    0    1                   CABLE NODE 3
      8    1      36.85          0.          0.    0    0    1                   CABLE NODE 4
     10    1      30.82          0.          0.    0    0    1                   CABLE NODE 5
     12    1      24.84          0.          0.    0    0    1                   CABLE NODE 6
     14    1      18.77          0.          0.    0    0    1                   CABLE NODE 7
     16    1      12.72          0.          0.    0    0    1                   CABLE NODE 8
     18    1       6.63          0.          0.    0    0    1                   CABLE NODE 9
     19    1       0.00          0.          0.    1    1    1                   FIXED NODE
      1    1    2    1    0    0            0.1    1              0.1     0.   0. ELEMENT
     18   18   19    1    0    1            0.     0              0.1     0.   0  ELEMENT
      1    0      0.014  0.0024             1.     6    0         0.1            MATERIAL
         0.11    0.0169                                                          STRAIN 2-1
         0.22    0.0375                                                          STRAIN 2-2
         0.33    0.0602                                                          STRAIN 2-3
         0.44    0.0845                                                          STRAIN 2-4
         0.55    0.1060                                                          STRAIN 2-5
         0.66    0.1289                                                          STRAIN 2-6
      1    0    -0.1081 0.1666667           0.     0    0         0.5     0.   0. 0 ANCHOR LOAD
LIVE      20    2    4    0    1    0    0    0    2    0    0.  -1  200    5    0 SUBANALYSIS
          0.1    0.0001   0.0001            1.        1.                         SOLUTION
      1    1    -33.916   1                                                      DISP.: ANCHOR
      1    2      1.019   1                                                      DISP.: ANCHOR
DYN        0    1    5    0    0    0    0    0    0    0    1   -1   90    5    0 SUBANALYSIS
          0.01  -0.0002  -0.0002            0.        0.          0.1   0.5      SOLUTION
          0.01       1.       100.          0.5 0.0833333          0.1   2.   10. TIME
END 0      1    1    2    2    3    3    4    4    5    5    5    6    7    7    8
1234567890123456789012345678901234567890123456789012345678901234567890123456789
```

Figure C-1. Data Deck for SEADYN Model of Run 6.

```
00001 CEL 60 FOOT EXPERIMENT-SEADYN MODEL-D.DILLON-RUN 11: RELAXATION-SEPT 79         CASE TITLE
00002     18    1    0    0   17    1    1    0    1    1    1    0.   0    0         MASTER CONTROL
00003     -2    0    32.1725 1.2817E-5   54.3394    1.6E-4    0.07528      60.       0. ENVIRONMENT
00004      1    0         0.     51.16        0.     0    0    1                     BUOY NODE
00005      2    0         0.     50.57        0.     0    0    1                     CABLE NODE 1
00006      4    1         0.     44.48        0.     0    0    1                     CABLE NODE 2
00007      6    1         0.     38.42        0.     0    0    1                     CABLE NODE 3
00008      8    1         0.     32.37        0.     0    0    1                     CABLE NODE 4
00009     10    1         0.     26.32        0.     0    0    1                     CABLE NODE 5
00010     12    1         0.     20.29        0.     0    0    1                     CABLE NODE 6
00011     14    1         0.     14.21        0.     0    0    1                     CABLE NODE 7
00012     16    1         0.      8.16        0.     0    0    1                     CABLE NODE 8
00013     18    1         0.        0.        0.     1    1    1                     FIXED NODE
00014      1    1    2    1    0    0    0.350   1              0.1       0.   0    ELEMENT
00015     17   17   18    1    0    1        0.   0              0.1       0.   0    ELEMENT
00016      1    0    0.0147    0.0020        1.   5    0         0.1                 MATERIAL
00017        0.11    0.0245                                                          STRAIN 1-1
00018        0.22    0.0509                                                          STRAIN 1-2
00019        0.33    0.0785                                                          STRAIN 1-3
00020        0.44    0.1060                                                          STRAIN 1-4
00021        0.55    0.1359                                                          STRAIN 1-5
00022      1    0    0.4060 0.2416667        0.    0    0         0.5       0.   0    0 BUOY LOAD
00023 LIVE     20    2    4    0    1    0.   0    0    2    0    0.  -1  200   5    0 SUBANALYSIS
00024         0.1    0.0001    0.0001        1.        1.         0.1       0.         SOLUTION
00025      1    1    29.659    1                                                     DISP: BUOY X
00026      1    2   -14.075    1                                                     DISP: BUOY Y
00027 DYN       0    1    5    0    0    0.   0    0    0    0    1   -1   90    5    0 SUBANALYSIS
00028        0.01   -0.0002   -0.0002        0.        0.         0.1      0.5         SOLUTION
00029        0.01         1.      100.       0.5 0.0833333        0.1       2.      10. TIME
00030 END 0     1    1    2    2    3    3    4    4    5    5    5    5    7    7    8
00031 1234567890123456789012345678901234567890123456789012345678901234567890123456789
```

Figure C-2. Data Deck for SEADYN Model of Run 11.

```
00001 CEL 60 FOOT EXPERIMENT-SEADYN MODEL-D.DILLON-RUN 15: ANCHOR LAST-SEPT 79         CASE TITLE
00002    19    1    0    0   18    1    1    0    1    1    1    0    0    0          MASTER CONTROL
00003     2    0  32.1725 1.2817E-5   54.0394   1.6E-4  0.07529        0.        70. ENVIRONMENT
00004     1    0    55.15         0.        0.    0    0    1                        ANCHOR NODE
00005     2    0    54.92         0.        0.    0    0    1                        CABLE NODE 1
00006     4    1    48.92         0.        0.    0    0    1                        CABLE NODE 2
00007     6    1    42.89         0.        0.    0    0    1                        CABLE NODE 3
00008     8    1    36.85         0.        0.    0    0    1                        CABLE NODE 4
00009    10    1    30.82         0.        0.    0    0    1                        CABLE NODE 5
00010    12    1    24.84         0.        0.    0    0    1                        CABLE NODE 6
00011    14    1    18.77         0.        0.    0    0    1                        CABLE NODE 7
00012    16    1    12.72         0.        0.    0    0    1                        CABLE NODE 8
00013    18    1     6.63         0.        0.    0    0    1                        CABLE NODE 9
00014    19    1     0.00         0.        0.    1    1    1                        FIXED NODE
00015     1    1    2    1    0    0     0.1    1             0.1       0.    0      ELEMENT
00016    18   18   19    1    0    1     0.     0             0.1       0.    0      ELEMENT
00017     1    0    0.014   0.0024       1.     6    0        0.1                    MATERIAL
00018        0.11   0.0169                                                           STRAIN 2-1
00019        0.22   0.0375                                                           STRAIN 2-2
00020        0.33   0.0602                                                           STRAIN 2-3
00021        0.44   0.0845                                                           STRAIN 2-4
00022        0.55   0.1060                                                           STRAIN 2-5
00023        0.66   0.1289                                                           STRAIN 2-6
00024     1    0   -0.2518 0.1666667     0.    0    0         0.6        0.    0    0 ANCHOR LOAD
00025 LIVE    20    2    4    0    1    0.   0    0    2    0    0   -1  200    5    0 SUBANALYSIS
00026         0.1   0.0001   0.0001      1.        1.                                SOLUTION
00027     1    1  -34.617    1                                                       DISP.: ANCHOR
00028     1    2    1.019    1                                                       DISP.: ANCHOR
00029 DYN      0    1    5    0    0    0    0    0    0    0    1   -1   50    5    0 SUBANALYSIS
00030        0.01  -0.0002  -0.0002      0.        0.         0.1       0.5          SOLUTION
00031        0.01       1.     100.     0.5 0.0833333         0.1       2.      10.1 TIME
00032 END 0    1    1    2    2    3    3    4    4    5    5    5    6    7    7    8
00033 123456789012345678901234567890123456789012345678901234567890123456789012345678900
```

Figure C-3. Data Deck for SEADYN Model of Run 15.

```
COLUMNS: 1         2         3         4         5         6         7         8 COLUMN
123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789  INDEX
 RUN 6 - ANCHOR LAST                                                             TITLE
SINGLE    FREE                FREEFALL            READ                           OPTIONS
      0.01                                                                       STATIC
       0.0     100.0       2.0                                                   TIME SPEC
       1.0       0.5                           2.                                INSTABILITY
                                                                                 SUPPORT
       0.0     -70.0                                                             BOUNDARY
    0                                                                            CURRENT POINTS
                                                                                 PROFILE
    1    15                                                                      NODES
   15    15                                                                      SEGMENTS
  0.5  0.5  0.5     0.2463    0.1081    0.0218    0.0218                         ANCHOR
      0.23     0.022     0.168    0.0128    0.0024               218.            CABLE MATERIAL
    0.7500    0.7500    0.7500    0.7500    1.5000    1.5000    1.5000    1.5000 HALF-SEGMENT
    1.5000    1.5000    1.5100    1.5100    1.5100    1.5100    1.5080    1.5080 HALF-SEGMENT
     1.508     1.508    1.495     1.495     1.495     1.495     3.035     3.035  HALF-SEGMENT
     3.025     3.025     3.045     3.045     6.630                               HALF-SEGMENT
    21.234              -1.019              21.200              -1.250           ANCHOR NODE
    20.950             -2.7500              20.690             -4.2400           NODE
    20.183             -7.2360              19.510             -10.200           NODE
    18.830             -13.168              17.830             -16.030           NODE
    16.832             -18.900              15.050             -21.300           NODE
    13.258             -23.695             10.4880             -23.544           NODE
    7.7180             -23.393              4.3280             -18.399           NODE
    2.4090             -12.626              1.0840             -6.6250           NODE
       0.0                 0.0                                                   FIXED NODE
                                                                                 PLOT-1
                                                                                 END
COLUMNS: 1         2         3         4         5         6         7         8 COLUMN
123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789  INDEX
```

Figure C-4. Data Deck for SNAPLOAD Model of Run 6.

```
00010 COLUMNS: 1        2        3        4        5        6        7        8 COLUMN
00020 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789  INDEX
00030  60 FOOT TEST NUMBER 11 - BUOY RELAXATION                                         TITLE
00040 SINGLE    FREE                FREEFALL            READ                            OPTIONS
00050       0.01 1000                                                                   STATIC
00060        0.0      100.0       4.0                                                   TIME SPEC.
00070        1.0        0.5                                                             INSTABILITY
00080        0.0        0.0                                                             SUPPORT
00090      100.      -10.0                                                              BOUNDARY
00100     0                                                                             CURRENT POINTS
00110        0.0        0.0                                                             PROFILE
00120     1    7                                                                        NODES
00130     7    7                                                                        SEGMENTS
00140   0.5  0.5  0.5            0.047    -0.406     0.046     0.046                    BUOY
00150       6.69      0.024      0.175    0.0128    0.0020    161.96                    CABLE MATERIAL
00160       3.03       3.03       3.03      3.03      3.03      3.03      3.02      3.02 HALF-SEGMENT
00170       3.04       3.04       3.03      3.03      8.16                              HALF-SEGMENT
00180     29.659                37.084              27.742              30.518          BUOY NODE
00190     25.747                24.662              23.438              18.954          NODE
00200     20.702                13.458              17.388               8.336          NODE
00210     13.227                 3.837               8.064               0.645          NODE
00220        0.0                   0.0                                                  FIXED NODE
00230 ZXTENSION                                    1                                    PLOT-1
00240                              10.             1                                    PLOT-2
00250    32                                                                             PLOT-3
00260                                                                                   END
00270 COLUMNS: 1        2        3        4        5        6        7        8 COLUMN
00280 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789  INDEX
```

Figure C-5. Data Deck for SNAPLOAD Model of Run 11.

```
00010 COLUMNS: 1         2         3         4         5         6         7         8 COLUMN
00020 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789  INDEX
00030  RUN 15 - ANCHOR LAST                                                            TITLE
00040 SINGLE    FREE                FREEFALL            READ                           OPTIONS
00050      0.01                                                                        STATIC
00060       0.0     100.0       4.0                                                    TIME SPEC.
00070       1.0       0.5                                  2.                          INSTABILITY
00080                                                                                  SUPPORT
00090       0.0     -70.0                                                              BOUNDARY
00100    0                                                                             CURRENT POINTS
00110                                                                                  PROFILE
00120    1    15                                                                       NODES
00130   15    15                                                                       SEGMENTS
00140   0.5  0.5  0.5    0.3980    0.2518    0.0218    0.0218                          ANCHOR
00150      0.23     0.022     0.168    0.0128    0.0024              218.              CABLE MATERIAL
00160    0.7500    0.7500    0.7500    0.7500    1.5000    1.5000    1.5000    1.5000 HALF-SEGMENT
00170    1.5000    1.5000    1.5100    1.5100    1.5100    1.5100    1.5080    1.5080 HALF-SEGMENT
00180     1.508     1.508   1.495       1.495    1.495     1.495      3.035     3.035  HALF-SEGMENT
00190     3.025     3.025     3.045     3.045     6.630                                HALF-SEGMENT
00200    20.533              -1.019              20.500              -1.250            ANCHOR NODE
00210    20.259             -2.749               20.018              -4.248            NODE
00220    19.535             -7.245               18.892             -10.218            NODE
00230    18.249             -13.191              17.297             -16.074            NODE
00240    16.344             -18.956              14.616             -21.397            NODE
00250    12.887             -23.837              10.138             -23.682            NODE
00260    7.388              -23.526              4.1170             -18.451            NODE
00270    2.2880             -12.649              1.0290             -6.6330            NODE
00280       0.0                 0.0                                                    FIXED NODE
00290 ZXTENSION                                  1                                     PLOT-1
00300                           10.              1    1                                PLOT-2
00310   64                                                                             PLOT-3
00320                                                                                  END
00330 COLUMNS: 1         2         3         4         5         6         7         8 COLUMN
00340 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789  INDEX
```

Figure C-6. Data Deck for SNAPLOAD Model of Run 15.

APPENDIX D

THE PLOT60 PROGRAM

APPENDIX D

THE PLOT60 PROGRAM

PLOT60 is a FORTRAN program that draws snapshot, trajectory, and tension history plots from the 60-foot experiment data files and overlays plots from SEADYN or SNAPLOAD output files. It is executed in quasi-interactive mode on the Control Data Corporation NOS timesharing computer system.

```
      PROGRAM PLOT60F
     + (INPUT, OUTPUT, TAPE1, TAPE2, TAPE3, TAPE4,
     + TAPE11, TAPE12)
C
C 2 APRIL 1980 VERSION
C
C PLOT SNAPSHOTS, TENSION HISTORIES, AND/OR NODE TRAJECTORIES
C FROM SEADYN OR SNAPLOAD OUTPUT TAPE1 WITH NODAL DATA ON TAPE11.
C AND TENSION DATA ON TAPE12.  TAPES 2 AND 3 ARE SCRATCH
C TAPE11 IS PACK60F OUTPUT. TAPE12 IS NEWTEN OUTPUT
C
C RESTRICTIONS:
C SERIAL SYSTEM ONLY WITH CONSECUTIVELY NUMBERED NODES AND
C ELEMENTS.
C 50 NODES MAXIMUM
C 50 CURVES ON ANY PLOT
C X VS Y SNAPSHOTS AND TRAJECTORIES
C POUNDS - FEET - SECOND UNITS
C
      REAL
     + TIME, XN, YN, ALEN, TIMD, CSTRT, TP,
     + STIM(50), TENS(50), X(50), Y(50),
     + XSTRT, YSTRT, FSTRT, TSTRT, TTOL(2), DTOL,
     + XSTEP, YSTEP, FSTEP, TSTEP,
     + XLEN,  YLEN,  FLEN,  TLEN
C
      INTEGER
     + INVX, INVY, INVT, INVF,
     + CFLAG, RUN, PRG, I, J, JPEN, KTIME, NODE,
     + NODEH, NODES, TELMS, TIMEH, TIMES, TIMEV, TNODS, DNODS, QNODS,
     + HTIME(2), HNODE(2), CTITLE(3), ETITLE(3), NTITLE(3),
     + TABLE(6,50), TELM(50), TNOD(50), FORM(4,2,6), FORM1(4),
     + FORM2(4), FORM3(4), FORM4(4), FORM5(4), FORM6(4)
C
C
      DATA CTITLE, ETITLE, NTITLE, HTIME, HNODE /
     + 10HCABLE SHAP, 10HE AT SELEC, 10HTED TIMES ,
     + 10HTENSION IN, 10H MAJOR ELE, 10HMENTS     ,
     + 10HTRAJECTORI, 10HES OF MAJO, 10HR NODES   ,
     + 4HTIME, 7H OTIME=, 4HNODE, 10H   NODE NO /
C
      DATA FORM /
     + 10H(5XA4,     , 10H7XA10)     , 10H           , 10H          ,
     + 10H(A7,       , 10HA10)       , 10H           , 10H          ,
     + 10H(E10.5)    , 10H           , 10H           , 10H          ,
     + 10H(F10.4)    , 10H           , 10H           , 10H          ,
     + 10H(12XA4)    , 10H           , 10H           , 10H          ,
     + 10H(A10)      , 10H           , 10H           , 10H          ,
     + 10H(15X3A10,  , 10H55X3A10)   , 10H           , 10H          ,
     + 10H(14XA10,A2, 10H,16XA10,A7, 10H,18XA10,A2, 10H)          ,
C
```

```
     + 10H(2E15.6,   , 10H10X)       , 10H           , 10H           ,
     + 10H(E12.5,    , 10H8XE17.10,  , 10H3X)        , 10H           ,
     + 10H(8XE12.6)  , 10H           , 10H           , 10H           ,
     + 10H(E12.5)    , 10H           , 10H           , 10H           /
C
      DATA RUN, INVX, INVY, INVT, INVF /1, 0, 0, 0, 0/
      DATA TTOL, DTOL /.001, .01, .001/
C
C ************************
C SELECT SEADYN OR SNAPLOAD MODEL SOURCE
      PRINT 1004
 1004 FORMAT (* 1=SEADYN  2=SNAPLOAD*)
      READ *, PRG
C FILL FORMAT ARRAYS BY MODEL
      DO 5 I=1,4
      FORM1(I) = FORM(I,PRG,1)
      FORM2(I) = FORM(I,PRG,2)
      FORM3(I) = FORM(I,PRG,3)
      FORM4(I) = FORM(I,PRG,4)
      FORM5(I) = FORM(I,PRG,5)
      FORM6(I) = FORM(I,PRG,6)
    5 CONTINUE
C SET FILE STATUS
      REWIND 1
      REWIND 2
      REWIND 3
      REWIND 4
      REWIND 11
      REWIND 12
C DEFINE PLOT SEQUENCE
C
      PRINT 1005
 1005 FORMAT (29H PLOT (0=LIST  1=AXES  2=ALL) )
      READ *, RUN
      PRINT 1010
 1010 FORMAT (
     + 37H HOW MANY NODES IN MODEL, EXPERIMENT )
C
      READ *, NODES, NODS
      IF (NODES .LE. 0) STOP
      PRINT 1040
 1040 FORMAT (
     + 38H HOW MANY SNAPSHOT TIMES AND TIME LIST )
C
      READ *, TIMES, (STIM(I), I=1,TIMES)
C
      PRINT 1020
 1020 FORMAT (
     + 40H HOW MANY TRAJECTORY NODES AND NODE LIST )
C
```

```
      READ *, TNODS, (TNOD(I), I=1,TNODS)
C     IF (TNODS .LT. 0) GO TO 275
      PRINT 1021
 1021 FORMAT ( 35H HOW MANY DATA TRAJ. NODES AND LIST )
      READ *, DNODS, (TNOD(I+TNODS), I=1,DNODS)
      IF (DNODS .LT. 0) GO TO 275
      QNODS=DNODS + TNODS
      IF (QNODS+TIMES .EQ. 0) GO TO 20
   10 PRINT 1022
 1022 FORMAT (
     + 25H FIRST STEP LENGTH X AXIS )
      READ *, XSTRT, XSTEP, XLEN
      PRINT 1024
 1024 FORMAT (
     + 25H FIRST STEP LENGTH Y AXIS )
      READ *, YSTRT, YSTEP, YLEN
      PRINT 1026
 1026 FORMAT (28H INVERT Y AXIS (0=NO  1=YES) )
      READ *, INVY
C
   20 PRINT 1030
 1030 FORMAT (
     + 43H HOW MANY ELEMENT TENSIONS AND ELEMENT LIST )
C
      READ *, TELMS, (TELM(I), I=1,TELMS)
      IF (TELMS) 275, 40, 30
   30 PRINT 1032
 1032 FORMAT (
     + 31H FIRST STEP LENGTH TENSION AXIS )
      READ *, FSTRT, FSTEP, FLEN
      PRINT 1034
 1034 FORMAT (
     + 28H FIRST STEP LENGTH TIME AXIS )
      READ *, TSTRT, TSTEP, TLEN
C
   40 IF (TNODS+TELMS+TIMES) 275, 275, 70
C
C *************************
C START AND REGISTER PLOTTER
C
   70 IF (RUN .EQ. 0) GO TO 72
      CALL PLOTS (53, 0, -4)
CZ    CALL DASHDF (0, 0., 0., 0.)
      CALL FACTOR (1.25)
      CALL PLOT (0., 0., -3)
      CALL PLOT (0., 6., 2)
      CALL PLOT (0., 0., 2)
   72 IF (TIMES .EQ. 0) GO TO 100
C
?
```

```
C ************************
C SET UP SNAPSHOT AXES
C
      IF (RUN .EQ. 0) GO TO 74
      CALL PLOT (2., 1., -3)
C X-AXIS
      CALL AXIS (0., 0., 4HFEET, -4, XLEN,  0., XSTRT, XSTEP)
      ALEN = XLEN + 2.
C Y-AXIS
      CALL AXIS (0., 0., 4HFEET,  4, YLEN, 90., YSTRT, YSTEP)
C CAPTION
CZ    CALL ASPECT (1.1)
CZ    CALL ITALIC (20.)
      CSTRT = .5*XLEN - 2.175
      CALL SYMBOL (CSTRT, -.65, .15, CTITLE, 0., 29)
CZ    CALL ASPECT (1.0)
CZ    CALL ITALIC (0.)
C SET TIME COUNTER
   74 IF (RUN .EQ. 1) GO TO 210
      KTIME = 1
C
C ************************
C FIND AND READ NEXT MODEL TABLE
C FIRST FIND TIME ENTRY
  100 READ (1, FORM1) TIMEH, TIMEV
      IF (EOF(1)) 200, 110
  110 IF (TIMEH .NE. HTIME(PRG)) GO TO 100
      DECODE (10, FORM2, TIMEV) TIME
C NEXT FIND COLUMN HEADER IN MODEL PRINTOUT
  115 READ (1, FORM3) NODEH
      IF (EOF(1)) 200, 120
  120 IF (NODEH .NE. HNODE(PRG)) GO TO 115
C NOW COPY MODEL PRINTOUT TABLE
      READ (1, FORM4) ((TABLE(I, NODE), I=1,6), NODE=1,NODES)
      IF (EOF(1)) 200, 130
  130 CFLAG = 0
      IF (TIMES .EQ. 0) GO TO 150
      IF (RUN .EQ. 0) PRINT 4030, TIME
 4030 FORMAT (F8.2)
  132 IF (KTIME .GT. TIMES) GO TO 150
      IF (TIME .LT. STIM(KTIME)-TTOL(PRG)) GO TO 150
      IF (TIME .LE. STIM(KTIME)+TTOL(PRG)) GO TO 135
      PRINT 2020, KTIME, STIM(KTIME)
 2020 FORMAT (I5, F12.3, 24H TIME NOT IN MODEL FILE. )
      KTIME=KTIME+1
      GO TO 132
C
C ************************
C PLOT 1 SNAPSHOT CURVE FROM MODEL
  135 CFLAG = 1
?
```

```
      JPEN = 3
      DO 140 J=1,NODES
      DECODE (40, FORM5, TABLE(1, J)) XN, YN
      YN=ABS(YN)
      CALL SCHEK (X(J), XN, XSTRT, XSTEP, XLEN, TIME, J, INVX)
      CALL SCHEK (Y(J), YN, YSTRT, YSTEP, YLEN, TIME, J, INVY)
      IF (RUN .EQ. 2) CALL PLOT (X(J), Y(J), JPEN)
      IF (RUN .EQ. 0)
     + PRINT 1050, J, XN, YN, X(J), Y(J)
 1050 FORMAT (I5, 4F12.3)
      JPEN = 2
  140 CONTINUE
      IF (CFLAG .EQ. 0) GO TO 150
C NOTE SNAPSHOT
      PRINT 4020, KTIME, STIM(KTIME), TIME
 4020 FORMAT (I5, 12H SNAPSHOT AT 2F9.2)
  149 KTIME = KTIME + 1
C
  150 IF (TELMS .EQ. 0) GO TO 170
C
C *************************
C COPY TENSIONS FOR SCRATCH FILE ON UNIT 2
C
      DO 160 I=1,TELMS
      DECODE (20, FORM6, TABLE(5, TELM(I))) TENS(I)
  160 CONTINUE
      IF (RUN .EQ. 0) PRINT 6020, TENS(1), TIME
      WRITE (2) TIME, (TENS(I), I=1,TELMS)
  170 IF (TNODS .EQ. 0) GO TO 190
C
C *************************
C COPY SCALED TRAJECTORIES TO SCRATCH FILE ON UNIT 3
C
      IF (CFLAG .EQ. 1) GO TO 180
      DO 175 I=1,TNODS
      J = TNOD(I)
      DECODE (40, FORM5, TABLE(1, J)) XN, YN
      YN=ABS(YN)
      CALL SCHEK (X(J), XN, XSTRT, XSTEP, XLEN, TIME, J, INVX)
      CALL SCHEK (Y(J), YN, YSTRT, YSTEP, YLEN, TIME, J, INVY)
      IF (RUN .EQ. 0)
     + PRINT 1050, J, XN, YN, X(J), Y(J)
  175 CONTINUE
  180 WRITE (3) (X(TNOD(I)), Y(TNOD(I)), I=1,TNODS)
C
C *************************
C CLOSE SNAPSHOT LOOP AND PREPARE FOR HISTORY LOOP
C
  190 IF (KTIME .LE. TIMES) GO TO 100
      IF (TELMS .GT. 0) GO TO 100
?
```

```
      IF (TNODS .GT. 0) GO TO 100
C
C FIND AND PLOT 1 DATA CURVE
C
  200 KTIME = 1
      J1 = TNODS+1
C FIND TIME IN NODAL DATA FILE
  441 READ (11, 5010) TIMEH, TIMEV
 5010 FORMAT (1XA4, 4XA7)
      IF (EOF(11)) 449, 442
  442 IF (TIMEH .NE. HTIME) GO TO 441
      DECODE (7, 5020, TIMEV) TIMD
 5020 FORMAT (F7.2)
      IF (RUN .EQ. 0) PRINT 6010, TIMD
 6010 FORMAT (10H DATA TIME  F9.2)
C SET SNAPSHOT TIME FLAG
      JPLT = 0
      IF (TIMES .EQ. 0) GO TO 444
  446 IF (TIMD .LT. STIM(KTIME)-DTOL) GO TO 444
      IF (TIMD .LE. STIM(KTIME)+DTOL) GO TO 448
      PRINT 5025, KTIME, STIM(KTIME)
 5025 FORMAT (I5, F12.3, 23H TIME NOT IN DATA FILE. )
      KTIME=KTIME+1
      GO TO 446
  448 JPLT=1
C READ HEADER LINES
  444 READ (11, 5030)
 5030 FORMAT (/)
C READ SCALE AND PLOT NODAL POSITION DATA
      JPEN=-3
      DO 443 J=1,NODS
      READ (11, 5040) XN, YN
 5040 FORMAT (2F8.2)
      IF (JPLT+DNODS .EQ. 0) GO TO 443
      CALL SCHEK (X(J), XN, XSTRT, XSTEP, XLEN, TIMD, J, INVX)
      CALL SCHEK (Y(J), YN, YSTRT, YSTEP, YLEN, TIMD, J, INVY)
      IF (RUN .EQ. 0)
     + PRINT 1050, J, XN, YN, X(J), Y(J)
C PLOT A SNAPSHOT POINT
      IF ((JPLT .NE. 1) .OR. (RUN .NE. 2) .OR. (X(J) .EQ. 0.)) GO TO 460
      CALL SYMBOL (X(J), Y(J), .05, 3, 0., JPEN)
      JPEN=-5
  460 IF ((KTIME .EQ. 1) .AND. (RUN .EQ. 0))
     + PRINT 1050, J, X(J), Y(J)
  443 CONTINUE
C COPY TRAJECTORY NODES TO UNIT 4
      IF (DNODS .GT. 0) WRITE (4) (X(TNOD(J)), Y(TNOD(J)), J=J1,QNODS)
C NEXT DATA TABLE (TO CURRENT SNAPSHOT
      IF (JPLT .EQ. 0) GO TO 441
C NOTE SNAPSHOT
?
```

```
      PRINT 4020, KTIME, STIM(KTIME), TIMD
      KTIME = KTIME + 1
      IF (KTIME .GT. TIMES) GO TO 210
      GO TO 441
  449 IF (TIMES .EQ. 0) GO TO 210
      IF (RUN .GT. 0) CALL PLOT (ALEN, 0., 3)
  210 IF (TELMS .EQ. 0) GO TO 240
C
C ************************
C SET UP TENSION AXES
      IF (RUN .EQ. 0) GO TO 216
  215 CALL PLOT (ALEN, -1., -2)
      CALL PLOT (2., 1., -3)
      CALL AXIS (0., 0., 7HSECONDS, -7, TLEN,  0., TSTRT, TSTEP)
      ALEN = TLEN + 2.
      CALL AXIS (0., 0., 6HPOUNDS ,  6, FLEN, 90., FSTRT, FSTEP)
CZ    CALL ASPECT (1.1)
CZ    CALL ITALIC (20.)
      CSTRT = .5*TLEN - 1.875
      CALL SYMBOL (CSTRT, -.65, .15, ETITLE, 0., 25)
CZ    CALL ASPECT (1.0)
CZ    CALL ITALIC (0.)
C
C ************************
C PLOT TENSION HISTORY CURVES FROM SCRATCH FILE
C
  216 DO 230 I=1,TELMS
      PRINT 4040, I, TELM(I)
 4040 FORMAT (I5, 19H TENSION IN ELEMENT I5)
      REWIND 2
      JPEN = 3
  217 READ (2) TIME, (TENS(J), J=1,I)
      IF (EOF(2)) 230, 220
  220 CALL SCHEK (TP, TIME, TSTRT, TSTEP, TLEN, TIME, TELM(I), INVT)
      CALL SCHEK (TNS, TENS(I), FSTRT, FSTEP, FLEN, TIME, TELM(I), INVF)
      IF (RUN .EQ. 0)
     + PRINT 1050, I, TIME, TENS(I), TP, TNS
      IF (RUN .EQ. 2) CALL PLOT (TP, TNS, JPEN)
      JPEN = 2
      GO TO 217
  230 CONTINUE
      IF (RUN .EQ. 0) PRINT 6020, TENS(1), TIME
 6020 FORMAT (F9.5, 8H TEN. AT  F9.2)
C
C GET TENSION DATA CURVE FROM UNIT 12
      REWIND 12
      READ (12, 5050)
 5050 FORMAT (///)
  232 IF (EOF(12)) 235, 234
  234 READ (12, 5060) TIME, TENS(1)
?
```

```
 5060 FORMAT (F8.2, 27XF9.5)
      IF (RUN .EQ. 0) PRINT 6020, TENS(1), TIME
      CALL SCHEK (TP, TIME, TSTRT, TSTEP, TLEN, TIME, TELM(I), INVT)
      CALL SCHEK (TNS, TENS(1), FSTRT, FSTEP, FLEN, TIME, TELM(I), INVF)
      IF (RUN .EQ. 0)
     + PRINT 1050, I, TIME, TENS(I), TP, TNS
      IF (RUN .EQ. 2) CALL SYMBOL (TP, TNS, .1, 3, 0., -3)
      GO TO 232
  235 IF (RUN .EQ. 2) CALL PLOT (ALEN, 0., 3)
  240 IF (TNODS .EQ. 0) GO TO 270
C
C *************************
C SET UP TRAJECTORY AXES
C
      IF (RUN .EQ. 0) GO TO 242
      CALL PLOT (ALEN, -1., -2)
      CALL PLOT (2., 1., -3)
      CALL AXIS (0., 0., 4HFEET, -4, XLEN,  0., XSTRT, XSTEP)
      ALEN = XLEN + 2.
      CALL AXIS (0., 0., 4HFEET,  4, YLEN, 90., YSTRT, YSTEP)
CZ    CALL ASPECT (1.1)
CZ    CALL ITALIC (20.)
      CSTRT = .5*XLEN - 2.025
      CALL SYMBOL (CSTRT, -.65, .15, NTITLE, 0., 27)
CZ    CALL ASPECT (1.0)
CZ    CALL ITALIC (0.)
C
C *************************
C PLOT TRAJECTORIES FROM UNITS 3 AND 4
C
  242 DO 260 I=1,TNODS
      PRINT 4050, I, TNOD(I)
 4050 FORMAT (I5, 19H TRAJECTORY OF NODE I5)
      REWIND 3
      JPEN = 3
  245 READ (3) (X(J), Y(J), J=1,I)
      IF (EOF(3)) 260, 250
  250 IF (RUN .EQ. 2) CALL PLOT (X(I), Y(I), JPEN)
      JPEN = 2
      GO TO 245
  260 CONTINUE
C NOW PLOT DATA TRAJECTORIES
      DO 360 I=1,DNODS
      PRINT 4050, I, TNOD(TNODS+I)
      REWIND 4
      JPEN = -3
  345 READ (4) (X(J), Y(J), J=1,I)
      IF (EOF(4)) 360, 350
  350 IF ((RUN .EQ. 2) .AND. (X(I) .NE. 0.))
     + CALL SYMBOL (X(I), Y(I), .05, 3, 0., JPEN)
C
```

```
      JPEN = -5
      GO TO 345
  360 CONTINUE
  265 IF (RUN .GT. 0) CALL PLOT (ALEN, 0., 3)
C
C ************************
C END OF JOB
C
  270 IF (RUN .EQ. 0) STOP
      CALL PLOT (ALEN, -1., -2)
      CALL PLOT (0., 0., 999)
  275 STOP
      END
C
C
C
      SUBROUTINE SCHEK
     + (XS, XD, XO, DX, XL, TM, ND, IX)
C
C SCALE AND CHECK A PLOT COORDINATE. ALLOW A PLOT POINT
C TO EXTEND 1-INCH BEYOND EITHER END OF THE DEFINED AXIS.
C
C XS SCALED COORDINATE RETURNED TO CALLER
C THE REMAINING ARGUMENTS ARE SUPPLIED BY CALLER:
C XD DATA VALUE TO BE SCALED
C XO AXIS LABEL AT START
C DX AXIS SCALE INCREMENT
C XL AXIS LENGTH
C TM TABLE TIME FOR XD
C ND TABLE NODE FOR XD
C IX INVERT OPTION (0=NO  1=YES)
C
C SCALE VALUE
      XS = (XD - XO)/DX
C
C INVERT POINT ON AXIS ON OPTION
      IF (IX .EQ. 1) XS = XL - ABS(XS)
C
C ALLOW 1-INCH UNDERFLOW
      IF (XS .LT. -1.) GO TO 10
C
C ALLOW 1-INCH OVERFLOW
      IF (XS .GT. XL+1.) GO TO 20
C
C RETURN VALID PLOT COORDINATE
      RETURN
C
C INVALID COORDINATE WARNING
   10 XS=0.
      GO TO 100
```

```
C
   20 XS=XL
  100 PRINT 1010, ND, TM, XD, XS
      RETURN
C
 1010 FORMAT (I4,
     + 24H NODE PLOT ERROR AT TIME  F7.1, 5XE11.4,
     + 16H VALUE SCALES TO  F9.3 )
C
      END
 -END OF FILE-
?
```

```
SET(R1=0)       BEGIN PLOT60F
GET,G=PLOT60X.    PLOT60X=PRECOMPILED
SET(R1=1)       PLOT60X ERROR FLAG
1RET, RETURN,S.   CLEAR S-FILE
IF(R1=0) GOTO,1EXT. BAD COMPILE
COMMENT. BEGIN CDYNVI PLOTS
GET,TAPE1=CDYNVI.      SEADYN OUTPT
GET,TAPE11=XVSZVI.     PACK60F OUTPT
GET,TAPE12=TENSVI.     NEWTENS OUTPT
DEFINE,NPFILE=NUTCVI.      NEUTRAL FILE
ATTACH,UNIPLOT/UN=LIBRARY. CDC PLOT PRC.
LIBRARY,UNIPLOT.       LOAD ROUTINES
SET(R1=1)       PLOT60X ERROR FLAG
G.       RUN PLOT60F
SET(R1=2)         VALID RUN
2RET,RETURN,TAPE1,TAPE2,TAPE3,TAPE4,TAPE11,TAPE12.
IF(R1=1) GOTO,1EXT. BAD RUN
GET,DR=ZETADRS.   UNIPOST DIRS.
ATTACH,UNIPOST/UN=LIBRARY. CDC POST-PRC.
DEFINE,PLOTF=ZETCVI. ZETC FILE
UNIPOST,I=DR,O=MSGVI.    FILL FILE
3RET,SET(R1=3)        VALID PROCESS
RETURN,PLOTF=ZETCVI.
RETURN,NPFILE=NUTCVI,MSGVI.
REWIND,DR.
COMMENT.  END  CDYNVI PLOTS
COMMENT. BEGIN CDYNXI PLOTS
ATTACH,TAPE1=CDYNXI.     SEADYN OUTPT
GET,TAPE11=XVSZXI.     PACK60F OUTPT
GET,TAPE12=TENSXI.     NEWTENS OUTPT
DEFINE,NPFILE=NUTCXI.      NEUTRAL FILE
SET(R1=1)       PLOT60X ERROR FLAG
G.       RUN PLOT60F
RETURN,TAPE1,TAPE2,TAPE3,TAPE4,TAPE11,TAPE12.
DEFINE,PLOTF=ZETCXI. ZETC FILE
UNIPOST,I=DR,O=MSGXI.    FILL FILE
4RET,SET(R1=4)        VALID PROCESS
RETURN,PLOTF=ZETCXI.
RETURN,NPFILE=NUTCXI,MSGXI.
REWIND,DR.
COMMENT.  END  CDYNXI PLOTS
COMMENT. BEGIN CDYNXV PLOTS
ATTACH,TAPE1=CDYNXV.     SEADYN OUTPT
GET,TAPE11=XVSZXV.     PACK60F OUTPT
GET,TAPE12=TENSXV.     NEWTENS OUTPT
DEFINE,NPFILE=NUTCXV.      NEUTRAL FILE
SET(R1=1)       PLOT60X ERROR FLAG
G.       RUN PLOT60F
RETURN,TAPE1,TAPE2,TAPE3,TAPE4,TAPE11,TAPE12.
DEFINE,PLOTF=ZETCXV. ZETC FILE
?
```

```
UNIPOST,I=DR,O=MSGXV.    FILL FILE
5RET,SET(R1=5)        VALID PROCESS
RETURN,PLOTF=ZETCXV.
RETURN,NPFILE=NUTCXV,MSGXV.
REWIND,DR.
COMMENT.  END CDYNXV  PLOTS
COMMENT. BEGIN SNAPXV PLOTS
ATTACH,TAPE1=SNAPXV.     SNAPLOAD OUTPT
GET,TAPE11=XVSZXV.     PACK60F OUTPT
GET,TAPE12=TENSXV.     NEWTENS OUTPT
DEFINE,NPFILE=NUTSXV.      NEUTRAL FILE
SET(R1=1)      PLOT60X ERROR FLAG
G.      RUN PLOT60F
RETURN,TAPE1,TAPE2,TAPE3,TAPE4,TAPE11,TAPE12.
DEFINE,PLOTF=ZETSXV. ZETS FILE
UNIPOST,I=DR,O=MSGXV.    FILL FILE
6RET,SET(R1=6)        VALID PROCESS
RETURN,PLOTF=ZETSXV.
RETURN,NPFILE=NUTSXV,MSGXV.
RETURN,DR.
COMMENT.  END  SNAPXV PLOTS
1EXT,RETURN,G,UNIPOST,UNIPLOT. CLEAR FILES
EXIT.       END RUN
IF(R1=0) GOTO,1RET. BAD COMPILE
IF(R1=1) GOTO,2RET. BAD PLOT60F
IF(R1=2) GOTO,3RET.
IF(R1=3) GOTO,4RET. UNIPOST RECOVERY
IF(R1=4) GOTO,5RET.
IF(R1=5) GOTO,6RET.
GOTO,1EXT.
 -END OF FILE-
?
```